RESERVOIR OPERATION USING MULTIPLE REGRESSED OPERATION RULES

A PROJECT SUBMITTED IN PARTIAL FULFILLMENT OF THE REQUIREMENTS FOR THE DEGREE OF

BACHELOR OF TECHNOLOGY
IN
CIVIL ENGINEERING

By

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NATIONAL INSTITUTE OF TECHNOLOGY ROURKELA

CERTIFICATE

This is to certify that the project report entitled, "**RESERVOIR OPERATION USING MULTIPLE REGRESSED MONTHLY OPERATION RULES**" submitted by **Sri Sanat Dash and Sri Subodh Panigrahi** in partial fulfillment of the requirements for the award of Bachelor of Technology Degree in Civil Engineering at the National Institute of Technology, Rourkela (Deemed University) is an authentic work carried out by him under my supervision and guidance.

To the best of my knowledge, the matter embodied in the project report has not been submitted to any other University/ Institute for the award of any Degree or Diploma.

Date:9-04-2008

Prof.A.K.Pradhan
Deparment of Civil Engineering
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I would also like to record my sincere gratitude to our HOD,Dr.K.C.Patra and all other faculty members and staff of Department of Civil Engineering, NIT Rourkela, for their goodwill and guidance received at appropriate times without which it would have been difficult on my part to finish the project work.

Date: 9.04.2008

Sanat Dash

Subodh Kumar Panigrahi.

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ABSTRACT

The object of the project is to find out the monthly draft (release) of water from a reservoir to a drought affected area using multiple regressed equations. The purpose is to find an optimal operating policy. i.e a schedule indicating volumes of water to be kept in storage or released from a storage facilities at given points in time.

The project involves the study of reservoir data of a drought affected area.

In the computation of the outflows the principle of multiple linear regression. In this method we have taken a dependent variable and 2 independent variables. These are related as in the equation:

$$Y=a+bX+cZ$$

where ,

a ,b ,c are constants.X and Z are independent variables.Y is the dependent variable

The project covers extensively about how to get the output from this equation.

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NOTATION

P_e = Probability of failure

P = number of time units during which storage is empty

n' = number of time units in the stream flow sequence

R_e = Reliability

R_v = Volumetric reliability

N = Period of analysis

n = Number of variables

Y(or yest) = Estimated value of the dependent variable (irrigation draft)

X_1 = Observed values of the dependent variable(irrigation draft)

$X_2,X_3,..X_n$=Observed values of the independent variables

X_1 = irrigation draft in ith month

X_2 = initial storage in ith month

X_3 = inflow into reservoir in ith month

X_4 = initial storage in the reservoir in the (i-1)th month

X_5 = Inflow into the reservoir in the (i-1)th month

a = Constant term of the regression equation

$b_2,b_3,..b_n$ = Regression coefficient(used in forecasting equation for irrigationdrafts)

$(Y-X_1)$ = Error of individual forecast

R = Multiple correlation coefficient (used for forecasting equation for irrigation drafts)

= Residual

$R_{1,23}$ = multiple correlation coefficient (with three variables)

$S_{1,23}$ = Standard error of estimate of X1 on X2 and X3

X = mean of dependent variables(X1)

S_1 = Standard deviation

$R_{1,2345}$ = multiple correlation coefficient (with five variables)

$S_{1,2345}$ = standard error of estimate of X1 on X2,X3,X4 and X5

Q_{i+1},Q_i = generated flow during (i+1) th , ith seasons (months) reckoned from the start of the synthesized sequences

Q_{j+1}, Q_j = mean flows during (j+1)th,jth seasons(months) within a repetitive annual cycle of seasons(if months are used , 1<=j<=12)

B_j = Least square regression coefficient for estimating (j+1)th flow from the jth flow and used in TF model)

t_i = Normal random variate used in TF model

S_{j+1}, S_j = standard deviations of flows during the (j+1)th month, jth seasons used in TF model

r_j = correlation coefficient between flows in jth and (j+1)th seasons

a = fraction of a

r'_{i+1}, r'_I = number at (i+1)th instant and ith instant

P = number of digits in pseudo-random number

C = A constant multiplier,0<C<1

A = non negative integer

X'_1, X'_2 = two rectangularly distributed deviates (0,1)

Y'_1, Y'_2 = normally and independently distributed deviates(0,1)

Area = Reservoir area

Z = Reservoir capacity

INTRODUCT ION

1.1. GENERAL:

Among many natural resources on earth the water is such a vital and important resource that the less said about it, the better. Its importance is so much felt by people living in arid environments and drought affected areas. They cry for water throughout the year. Only after such a basic need is satisfied, they look for any-thing else — food, job and shelter, etc. How such a rare and vital resource can best be utilized for human use and how efficiently this can be managed are the burning questions raised all over the world today in greater intensity than ever before.

There are no wanting proofs that ever since the dawn of civilization, the intelligent and perseverant man has ever tried to divert the available surface water and use it for his agricultural and other allied purposes. But to his great misfortunes the nature has always behaved in a strange way. Very often he is victimized by the nature’s most cruel act — erratic or no rain. This results into severe droughts— very poor or no agricultural outputs and finally the outcome of a famine in the most disastrous form. His long built civilization and material progress are stopped and even disappear altogether.

Now coming to real problem of India, One sees that about 80% of its population mainly depends on agriculture. Under the present situations of its rapid population growth, there is always a heavy pressure for exploitation of available water resource in the best possible manner, to meet the increasing demand for food. There is ever increasing need for irrigation for better agricultural outputs and fight against hunger, diseases and other wants.

Under the circumstances, it comes to mind automatically to realize the great importance of water resource management schemes and the vital roles to be played by the concerned water resource engineers or hydrologists. These useful technocrats have desired and hoped that they should find out better operating policies of storage reservoirs, contribute better know—hows for transfer of water in the judicious ways and for the economic use of available water supply and devise similar other policies. They are entrusted with the task of constructing reservoirs, to manage them more efficiently and help in building a sound economy to the nation and the people.

There are rays of hope now that much emphasis is placed countrywide for the development and management of water resources, in spite the limitations that there are political and legal problems. All efforts are being made in the national level with directives to the concerned organization to upgrade the socio-economic condition of the poor people through rational planning of water resources projects and following improved operational policies.

It may be appropriate to mention here that no water resource system is free from problems. It may be due to the fact that water is often available at times; the amount of water available is not upto the demand. Besides there is a maldistribution of water in space and time.

On the whole the water resource system is developed on a huge cost. It should not be allowed to fail to serve its purpose. Although it may be admitted that a reservoir project may yield benefits in long terms, but its failure to supply water at the time of acute need cannot be ignored. This may be due to adopting a very poor operating policy and management.

From the foregoing discussion it is now clear that a water resource project with efficient management and improved operational policy can establish real hopes for the aspirants and build a strong edifice for overall progress.

1.2. REVIEW :

Many advanced theories and methods are contributed by several research workers in the field of water resource system. Either they are aimed at finding out criteria for the optimal design of system elements such as dam, reservoirs etc., or target outputs for irrigation water or in optimal operating policy i.e. a schedule indicating volumes of water to be kept in storage or released from a storage facilities at given points in time.

Due to advent of high speed computers along with the new knowledge on system analysis, this field of water resources planning management open out with new methodology. This methodology, rather the tool of the discipline, aims in integrating all possible functions of the reservoirs. A certain pattern of reservoir behavior in future remain apparently clear and also a statement of future risk is explained.

It is now worthwhile to review a few such works which are based on linear programming, dynamic programming and simulation techniques ,etc.

LINEAR PROGRAMMING :

It is concerned with solving a specific type of problem called optimization problem: " one in which all relations among the variables are linear both in the function to be optimized and the constraint. This linear programming technique has found extensive use in design and operation of reservoirs with certain degree of success.

DYNAMIC PROGRAMMING:

"Dynamic programming is a way of viewing a problem". Problem involving a sequential decision making processes can be solved by the application of dynamic programming. "It investigates the conditions over which an overall best can be achieved".

The operating policies involve a sequence of decision to be optimized over time. The optimization is possible through the application of dynamic programming.

SIMULATION:

“Simulation is defined as a process duplicating the essence of a system or activity without attaining reality itself”. It is essentially a search technique which resembles the trial and error approach used in traditional operation studies. In simulation less flexibility is there for the operating procedure, which is once fixed in the program.

Many situations encountered in planning and designing water resource system involve rigorous mathematical methods difficult to solve. Simulation helps to avoid such difficulty. It incorporates quantitative relationships among the variables and describes the outcome or response of the operating system under a given sets of inputs and operating conditions.

1.3. THE STUDY:

In the present context work is undertaken to find out monthly operation rules for the proposed Uduthorehalla reservoir project in the state of Karnataka and study the behavior of the reservoir in future under the adopted operation rule.

The Uduthorehalla reservoir project fulfilled this basic aim of the study. Further in view of the persistent demand from the people of Kollegal Taluk of Mysore district of Karnataka State who are facing drought situations very often and suffering a lot, this proposed reservoir project found a valid place for study and determining suitable operation policy so as to mitigate drought situations and to provide the people some positive reliefs.

In the problem the principle of linear multiple regression is adopted in determining monthly operation rules for the above reservoir which is supposed to meet the irrigation requirement in the best possible manner under drought situations. In this approach of multiple regression adopted for reservoir operation, the monthly irrigation draft is considered as function of storages and inflows of the same month. This storage corresponds to the values at the beginning of the month.

The principle of least square criterion is applied in framing the multiple regressed monthly operation rules.

Several approaches using linear programming, dynamic programming and simulation may be available for operation of surface reservoirs. But such simple monthly operation rules using multiple regressed equations perhaps are rarely used for the purpose of meeting drought conditions.

(i) In the study the reservoir operation tables of twenty six years (1950—51 to 1975—76) prepared by the concerned organization of the proposed Reservoir project was considered. The actual monthly irrigation drafts as possible were found out for all the twenty six years taking into consideration the corresponding monthly inflows and the storage values. Certain features like the designed dead storage capacity and reservoir capacity, etc. of the dam were unchanged while computing the available water to be released for monthly draft. The month to month evaporation volumes were also incorporated.

These monthly possible drafts of twenty Six years were considered as function of the storages and inflows in the same month. Applying principle of square criterion, the multiple linear regressed equation were found out. The multiple correlation coefficients were also computed for multiple regressed equations. The equations with higher multiple correlation coefficients are accepted as the final set of monthly multiple regressed equations to be adopted as monthly operation rules.

(ii) . In Chapter 2 details about the Basin system and the problem undertaken here are given.

(iii). In Chapter 3 the theory adopted here to formulate the monthly operating policies and the different criteria of analysis for the reservoir operation are incorporated.

(iv). The analysis cannot be conclusive unless there is a large series of data. Here only twenty six years of flow data are available originally. Hence Thomas Fiering model (1.18) is utilized for sequential generation of monthly stream flow data up to a period of fifty years. Details about the sequential generation process of flow data are discussed in Chapter 4.

(v). Reservoir operation is carried out in Chapter 5 through computer programs for 26 years of available flow data as well as for 50 years of generated flow data in natural series. The reservoir operation carried though computer programs by not using the adapted operation policy in first case and using the multiple regressed monthly operation policy in the second, gave valuable information regarding the effectiveness of the newly adapted monthly operation policy.

(vi). A concluding remark is given at the end in Chapter 6. Possible suggestions are also incorporated after a good deal of discussions on the work.

THE BASIN AND THE SYSTEM

2.1. THE RIVER SYSTEM:

The present proposal envisages construction of a Medium Irrigation Project by building a storage reservoir across Uduthorehalla system in the Mysore district of Karnataka
The proposed reservoir project being of composite nature comprises of earth dam in the gorge portion and flanks with a flank waste weir of masonry on the right bank hill mound, for allowing the flushing of flood waters and meeting the parent nallah at a downstream.

The stream traverses for a length of 64.34 kilometers and meet river 'The Cauvery' finally. The basin map is shown in figure.

The total drainage area of the stream is 318.56 square kilometers and that at the dam site is only 202 square kilometers. The stream carries flows in the major or full period of the year. Thus it can be designated as a semi perennial to perennial stream.

The annual rainfall of the area is as high as 635 to 1,397 millimeters, annual average being 965 mil1imtros at the upstream of the catchment upto the proposed reservoir site.

Observed stream flow records are available only for six years from 1970—71 to 1975—76. By developing monthly cumulative rainfall—runoff relationships on the basis of rainfall data, the yield is assessed at the dam site. Thus the cumulative rainfall—runoff relation is:

$$R = 0.23\ P — 1.23$$

This is derived by regression analysis.
Here.,
P = Cumulative monthly weighted average rainfal1 of catchment area in inches.
R = Cumulative monthly runoff of catchment area in inches at Dam site.

In Appendix ‘B’ the monthly weighted average rainfall of catchment area are furnished. The monthly yeild series from 1950—51 to 1975—76 are given in Table 2.1 and estimated yeild series from 1950—51 to 1975—76 on annual basis are furnished in Appendix—C.

The project is intended to mitigate drought situation recurring very often in the area. The proposed annual utilization of water for irrigation is 33.32 million cubic—meters to give benefits through Canal system to 6,272.50 hectares of mixed cropping pattern. Further this project assures additional supply to wet ayacut of 323.88 hectares downstream under Gundapuram anicut.

The irrigation demand pattern proposed for the ayacut under the scheme (2.1) and adopted accordingly in the problem is furnished in table 2.2. The demand pattern is also represented graphically in Fig. 2.3 in Fig. 2.4 both in volume and percentage basis. The principal crops grown in the area are dry crops viz. Ragi, Jowar and Ground nut etc. Mulbery is also grown in certain area. Under the present proposal, same type of cropping pattern such as Kharif , Semidry, Rabi Semidry and Mulbery (Perenial) including the existing pattern (paddy) under Gundapuram anicut is included.

The monthly evaporation values in meters/unit area of waterspread as incorporated in the project report and also considered in this problem is given in table 2,3 and same is represented graphically in Fig. 2.5.

Similarly the reservoir area and corresponding capacities at different elevation given in the project report are tabulated in table 2.4.

The salient features of the proposed scheme is furnished in table 2.5.

2.2. THE PROBLEM:

The proposed Uduthorehalla Reservoir project (2.1) has a storage capacity of 21.23 million cubic meters. The Dead storage capacity is kept at 4.16 million cubic meters. The estimated 50% dependable years yield at dam site is 37.27 million cubic meters, and 75% dependable year ‘s yield is 28.89 million cubic meters.

The Gross commanded area under the scheme (2.1) is 8,597 hectares and the culturable commandable area proposed for fresh irrigation is 6,272.5 hectares. The existing wet ayacut of 323.88 hectares under Gundapuram anicut will also receive water from this proposed project for irrigation.

The project is intended to provide irrigation to dry areas of Kollegal Taluk in Mysore district which faces chronic droughts very frequently due to erratic and failure of rains.

Now that an irrigation scheme is proposed by the concerned authority to provide certain relief measures to the people of the drought—prone area, it is very much imperative on the part of the agency who executes the scheme to devise a suitable operation policy and implement the same, so that the limited amount of water that may be available in the reservoir during both normal and drought periods, can be used in the best possible manner. Every drop of water is so valuable in the area that its wastage is intolerable. There should be motives behind this policy to save some water in the reservoir judiciously, distribute it in right manner so as to make timely utilization. This aspect is very important.

Thus in the present problem keeping in view of the above facts an operation policy is to be devised so as to be applied in the reservoir operation and if found effective the same can very well be adoptable as an operation policy of the proposed scheme in future.

Several approaches may be available with their effects on different criteria on reservoir operation. But no such information is available on the performance of these methods under drought conditions. Complicated system approaches using Linear programming, dynamic programming and simulation techniques are now widely used, due to the advent of digital computers. But rarely the operation techniques, based on principle of multiple regression, are formulated for purposes of reservoir operation.

Thus sincere effort is put here to formulate an operation policy based on principle of multiple regression so as to be examined as regards to its effectiveness, specially under drought condition.

But in the project report only a very short period of historical flows are available, where it is but a handicap to study the reservoir behavior in a. complete and proper manner. The existing working table represents only for twenty six years whereas the life of the project is about fifty years. However, this working table is found usefu1 in the work to formulate the multiple regressed monthly operation policy.

In order to avoid the shortcoming due to short period of streamflow and to avoid such a dilemma as regards the dependence on reservoir operation results with a short duration of data, the Thomas and Fiering model, as a data generation technique has been considered here as the most practical one. By this method data for as long a period as necessary can be generated and utilized to the problem. In fact the same is followed here to as certain the utility of the operation policy based on the principle of multiple regression, from knowing the definite patterns of reservoir behavior by the application of the policy for the entire life period of the reservoir.

Table.2.1. ORIGINAL FLOW DATA (26 YEARS), in million cubic meter

YR.	APRIL	MAY	JUN	JUL	AUG	SEPT
1	0.00000	5.94510	0.14155	0.82099	8.94596	18.62798
2	0.76437	8.15328	1.50043	5.88848	2.40635	3.56706
3	0.00000	0.00000	0.00000	0.82099	1.58536	2.15156
4	0.99085	13.56049	8.91765	4.13326	1.41550	6.39806
5	0.00000	2.01001	1.52874	4.16157	7.21905	0.62282
6	0.00000	6.31313	4.07664	2.15156	3.85016	2.03832
7	0.00000	0.00000	0.99085	6.14327	3.51044	4.24650
8	0.00000	11.32400	2.32142	2.83100	3.48213	6.14327
9	0.00000	4.41636	3.19903	5.83186	7.33229	5.46383
10	0.00000	4.69946	.57793	4.02002	7.81356	9.28568
11	0.00000	0.00000	2.15156	15.06092	8.01173	8.57793
12	0.00000	0.00000	4.30312	2.20818	1.78353	1.64198
13	0.00000	18.03347	1.78353	1.78353	8.83272	5.80355
14	0.00000	1.84015	1.24564	1.89677	4.16157	2.23649
15	0.00000	4.16157	1.21733	11.40893	0.45296	6.76609
16	0.00000	0.45296	0.25479	1.89677	5.32228	3.28396
17	0.00000	3.48213	0.36803	10.05005	1.69860	10.58794
18	0.00000	0.00000	2.40635	4.95425	0.39634	0.00000
19	0.00000	4.75608	1.47212	0.00000	1.64198	11.01259
20	0.00000	3.28396	0.33972	3.19903	8.97427	2.46297
21	0.00000	0.28310	0.00000	4.78439	4.50129	3.45382
22	0.31141	2.57621	0.59451	0.87761	7.04919	14.91937
23	2.54790	1.81184	0.76437	2.83100	1.44381	2.94424
24	0.50958	4.27481	2.63283	3.99171	6.65285	7.13412
25	0.02831	1.95339	2.54790	3.02917	4.27481	10.24822
26	0.14155	1.92508	0.22648	1.84015	2.68945	8.09666

ORIGINAL FLOW DATA (26 YEARS),in million cubic meters

YR	OCTOBER	NOVEMBER	DECEMBER	JANUARY	FEBRUARY	MARCH
1	12.03175	0.39634	0.00000	0.16986	0.00000	1.27395
2	5.63369	6.65285	0.00000	0.00000	0.00000	0.00000
3	3.02917	0.00000	6.87933	0.00000	0.11324	0.00000
4	10.61625	5.03918	0.28310	0.45296	0.00000	2.97255
5	13.95683	0.00000	3.48213	0.67944	0.45297	0.11324
6	10.44639	1.18902	2.03832	0.00000	0.00000	0.00000
7	19.76038	7.44553	1.01916	0.00000	0.00000	0.42465
8	11.15414	7.78525	0.08493	0.05662	0.05662	1.33057
9	5.23735	6.65285	0.00000	0.28310	0.82099	0.00000
10	6.93595	2.71776	0.93423	0.00000	0.00000	0.25479
11	11.06921	8.12497	0.76437	2.37804	0.70775	0.08493
12	4.61453	4.02002	0.19817	0.00000	0.42465	0.39634
13	12.08837	0.76437	2.32142	0.00000	0.00000	0.00000
14	10.87104	1.27395	2.32142	0.00000	0.00000	0.00000
15	11.38062	5.15242	1.27395	0.00000	0.00000	0.00000
16	3.85016	1.30226	2.71776	0.00000	0.00000	0.00000
17	9.85188	15.57050	0.65113	2.12325	0.00000	0.50958
18	5.94510	1.27395	1.95339	0.00000	0.00000	0.00000
19	6.96426	5.32228	1.24564	0.00000	0.00000	0.00000
20	8.12497	5.18073	4.89763	0.33972	0.00000	0.45296
21	11.74865	5.86017	2.83100	0.90592	0.76437	0.62282
22	10.53132	6.19989	6.42637	1.41550	0.76437	0.36803
23	8.54962	3.31227	30.80128	3.39720	0.96254	0.62282
24	2.71776	1.84015	1.07578	0.50958	0.33972	0.00648
25	2.37804	0.96254	0.00000	0.00000	0.45296	0.00000
26	4.30312	4.55791	0.82099	0.19817	0.11324	0.08493

Table 2.2.MONTHLY DEMAND FOR IRRIGATION

SI NO.	MONTH	DEMAND (IN MILLION CUBE FEET)	DEMAND(IN MILLION CUBIC METERS)	% OF ANNUAL REQUIREMENT
1	APRIL	73	2.07	6.2
2	MAY	20	0.57	1.7
3	JUNE	50	1.42	4.2
4	JULY	54	1.53	4.6
5	AUGUST	229	6.48	19.5
6	SEPTEMBER	155	4.39	13.2
7	OCTOBER	77	2.18	6.5
8	NOVEMBER	188	5.32	16
9	DECEMBER	101	2.85	8.6
10	JANUARY	77	2.18	6.5
11	FEBRUARY	77	2.18	6.5
12	MARCH	76	2.15	6.5
	TOTAL	1,177	33.32	100.0

Table 2.3. MONTHLY EVAPORATION LOSSES FROM RESERVOIR

SI. NO	MONTHS	RATE OF EVAPORATION, IN INCH /UNIT AREA OF WATER SPREAD	RATE OF EVAPORATION, IN METRE /UNIT AREA OF WATER SPREAD
1	April	9	0.22860
2	May	10	0.25399
3	June	7	0.17779
4	July	6	0.15240
5	August	6	0.15240
6	September	6	0.15240
7	October	5	0.12698
8	November	4	0.10159
9	December	4	0.10159
10	January	4	0.10159
11	February	4	0.10159
12	March	7	0.17779

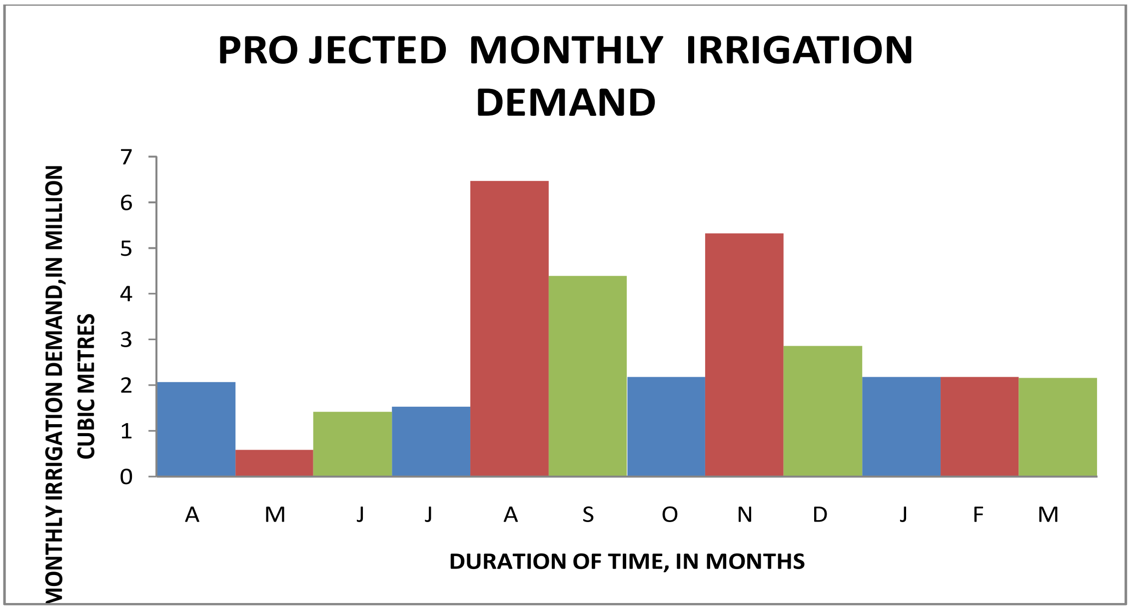


fig. 2.1. PROJECTED MONTHLY IRRIGATION DEMAND

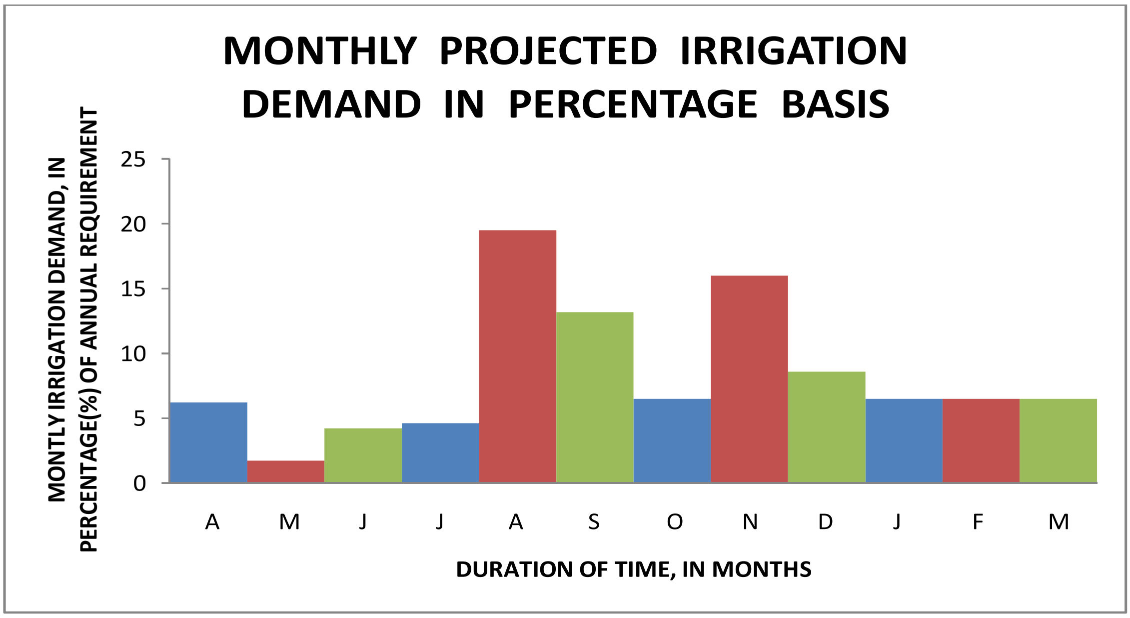


fig.2.2.PROJECTED MONTHLY IRRIGATION DEMAND
IN PERCENTAGE BASIS

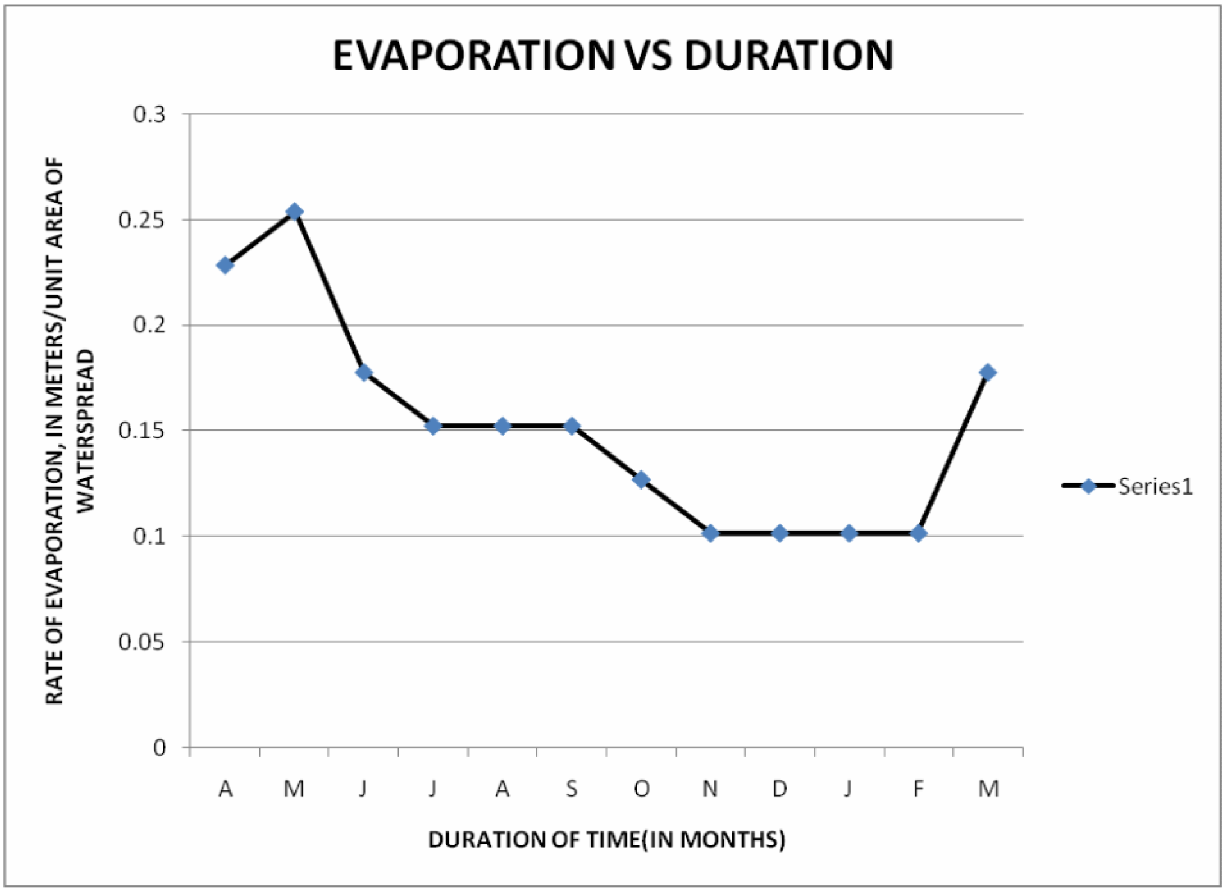


Fig.2.3.EVAPORATION VS DURATION CURVE

Table 2.4.AREA CAPACITY TABLE

SI NO.	REDUCED LEVEL, IN METRE	RESERVOIR AREA, IN MILLION SQUARE M	RESERVOIR CAPACITY IN MILLION CUBIC M
1	667.21	0.0	0.0
2	669.34	0.00627	0.01600
3	672.39	0.01640	0.03340
4	675.44	0.08590	0.17500
5	678.48	0.21740	0.62200
6	681.53	0.32540	1.44350
7	684.58	0.44320	2.60990
8	687.63	0.58890	4.17690
9	690.68	0.71270	6.15660
10	693.72	0.82220	8.49220
11	696.77	0.97070	11.22010
12	699.82	1.06450	14.32000
13	702.87	1.17400	17.72860
14	705.62	1.37590	21.23250

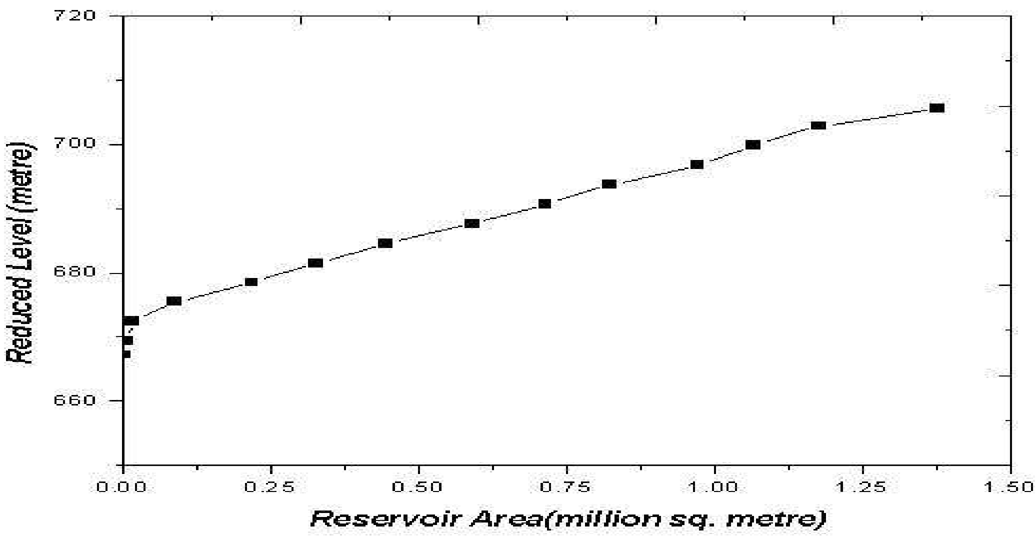


fig2.4.reduced level vs reservoir area

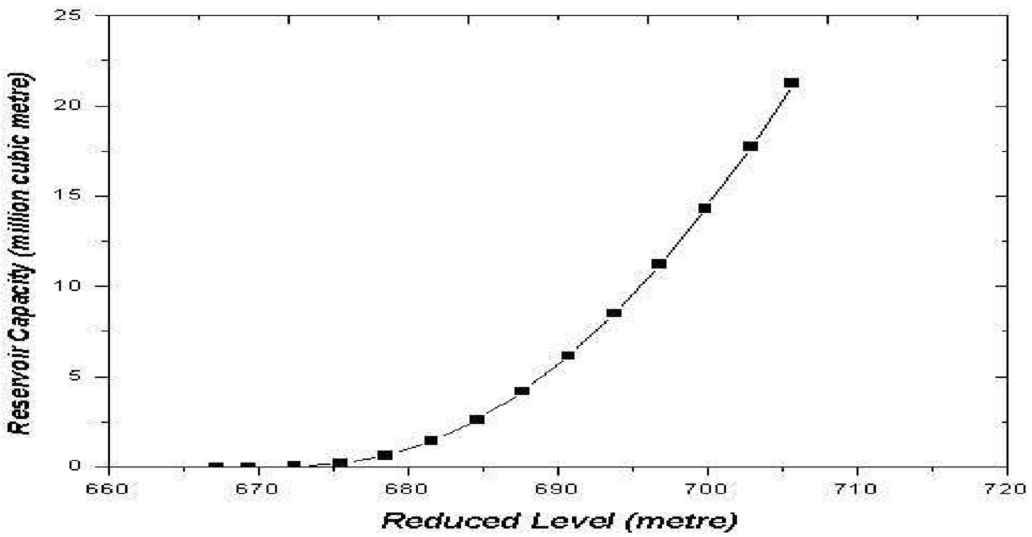


Fig 2.5.reduced level vs reservoir capacity

Table.2.5.SALIENT FEATURES OF UDUTHOREHALLA RESERVOIR PROJECT

1.Location	Longitude 77˚ 19 ’ 58 ” E Latitude 11˚ 55 ’ 58 ” N
2.Catchment area at damsite	202 sq kms
3.Mean annual precipitation	965 mm
4.Dependable annual yield at dam site	
(a)50% dependable yield	37.27 million cubic meters
(b)75% dependable yield	28.89 million cubic meters
5.Gross storage capacity of reservoir	21.23 million cubic meters
6.Dead storage capacity	4.16 million cubic meters
7.Live or active storage capacity	17.07 million cubic meters
8.Dead storage level	687.63 meters
9.Full reservoir level	708.66 meters
10.Top of dam	712.00 meters
11.Average river bed level	667.40 meters
12.Area of water spread	137.60 hectares

13.Type of dam	Composite dam
14.Length of dam	1539.25 meters
15.Maximum flood discharge	757.30 cumecs
16.Gross command area	8579.2 hectares
(a)Left bank	3197.00 hectares
(b)Right bank	5382.2 hectares
17.Irrigable command	6272.5 hectares
(a)Left bank	2509.0 hectares
(b)Right bank	3763.5 hectares
18.Annual irrigation demand	33.32 million cubic meters

THEORY

3.1 GENERAL:

Several research workers have contributed different methods of reservoir operation policy in different time. But no such information is available on the performance of these methods as to their effectiveness under drought conditions. Reservoir operation study being a major hydrologic problem, further and further researches are necessary to find out more effective operation techniques, specially under situations of droughts.

For greater research in this field certain prerequisites like hydrologic data such as available stream flows into the reservoir, probable demand of water with its seasonal distribution, optimum design of storage capacity and other relevant informations are necessary.

However, in the problem the flow data and its pattern with seasonal distribution, the month wise distribution of demand pattern and tentative optimum storage capacity of the reservoir etc. are available. It only emphasizes the need to determine a suitable operation policy with the above information.

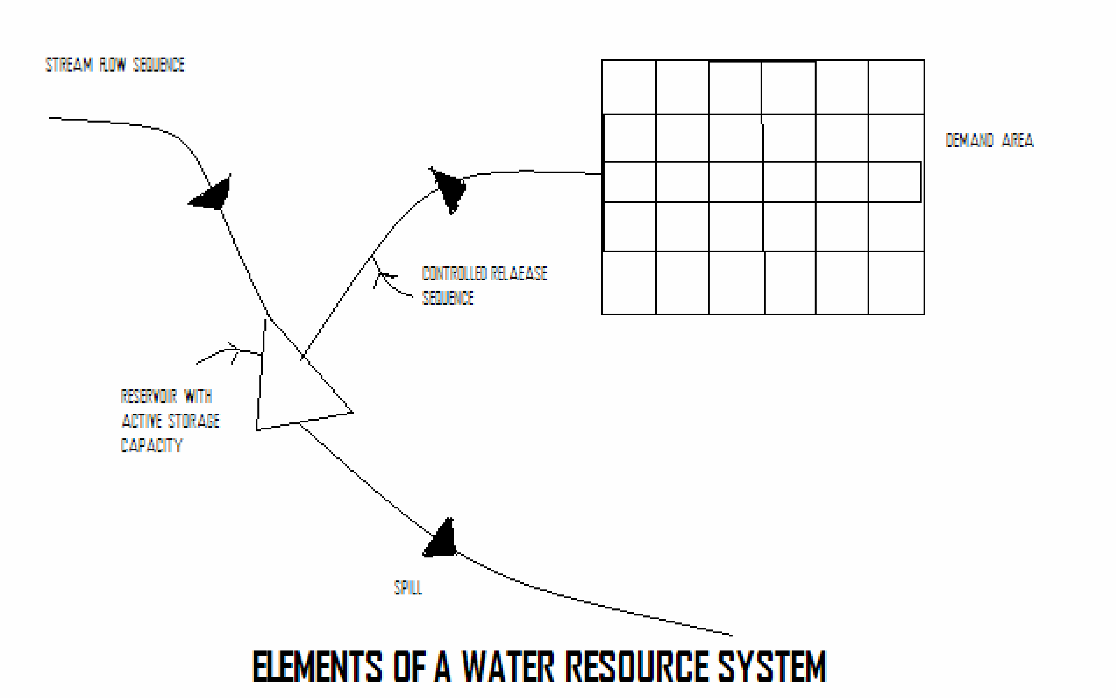


Fig. 3.1.ELEMENTS OF WATER RESOURCE SYSTEM

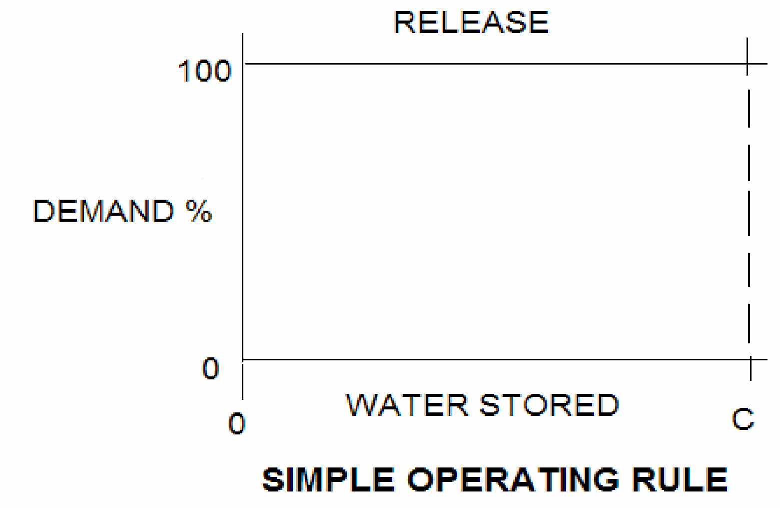
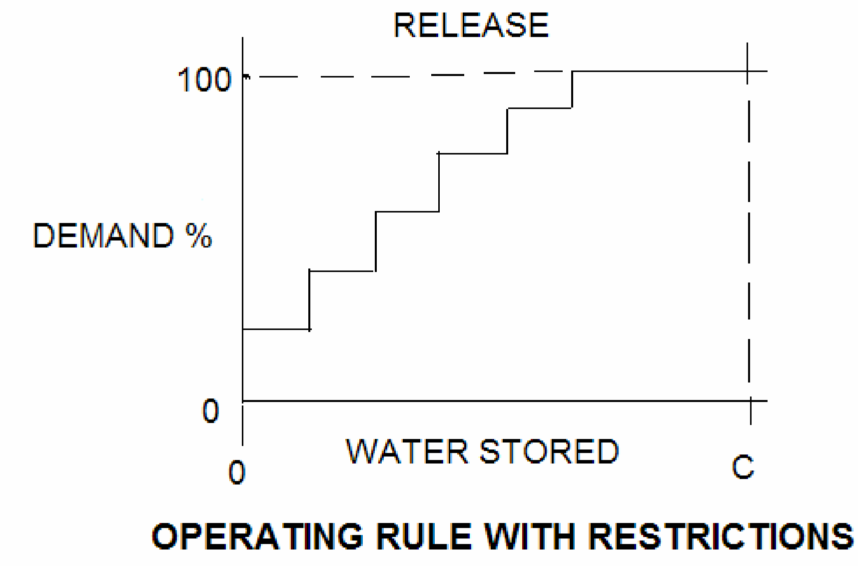


fig. 3.2(A)SIMPLE OPERATING RULE



(B)OPERATING RULE WITH RESTRICTIONS

3.2 DEFINITION OF TERMS:

Active Storage: Active storage of a reservoir is the water stored above the level of he lowest off take. It is equal to the total volume of water stored less the volume of 'dead' storage (the volume below the level of off take).

Release or Draft: Release is the volume of controlled water released from a reservoir during a given time interval. It describes regulated flow from the reservoir.

Spill : Spill is the uncontrolled flow from the reservoir and will take place only when the water stored in the reservoir is above full supply level.
The above three terms are illustrated in form of a Schematic diagram as shown in figure.

Operation or Release rule: Usually the volume of water released from a reservoir is equal to the volume of water required or demanded by the consumers. There may be periods when either the reservoir level is so low that the water required cannot be supplied, or that prudence dictates that only part of the water demanded can be released from storage. Another factor may be the time of the year or the expected inflows for the subsequent period.

Thus the way in which the draft or release is controlled is the release or the operating rule. The simplest operation rule is to supply all of the water demanded. In this situation, the draft is independent of reservoir content and season. If there is insufficient water in the reservoir to meet the required draft, the storage empties. As the volume of water stored in he headwater reservoir decreases, restrictions are placed on users, so that demand falls and releases are lowered. The example of two operating rules (A) simple operating rule (B) Operating rule with restrictions are illustrated in figure.

Probability of Failure (Pe): The probability of failure is the proportion of time units during which the reservoir is empty to the total no. of time units used in the analysis.

Hence, Pe =P/n .

Where, Pe = the number of time units during which the storage is empty.

n = the total number of time units in the stream flow sequence.

Reliability (Re): The corresponding definition of reliability is defined as

Re = 1—Pe.

This definition enables comparison to be made between different methods.

Volumetric Reliability (Rv): It relates to the volume of water supplied to the volume of water demanded for the study period i.e.—

Rv=actual supply/demand

The definition has merit for overall reservoir performance.

Shortage index : Shortage index is defined as the sum of the squares of annual shortage ratios for the analysis period, converted to a 100 years base.

Shortage index=(100/N) x $\sum$(annual storage/annual requirement)^2

where N = period of analysis.

Shortage index is a measure of the number and magnitude of annual shortages. Lower shortage index indicates that it is more adequately meeting the target requirements.

3.3 MULTIPLE LINEAR REGRESSION:

PRINCIPLE OF MULTIPLE LINEAR REGRESSION

The degree of relationship existing between three or more variables is called multiple regression (correlation) when there exists linear re1ations among variables it is linear correlation.

Multip1e regression is an extension of the simple, two variable regression procedures. A two variable linear regression is expressed by an equation of the form

$$Y = a + bX$$

where,

Y is dependent variable

X is independent variable

The correlation is expressed as positive or negative (inverse) according as Y increases or decreases depending upon the value of X. On plotting the above equation on a rectangular coordinates the two constants a and b, are the Y intercept and the slope respectively of the resulting regression line.

But in case of multiple linear regression where the independent variables are increased the relationship is expressed in the form

$Y = f(X_2, X_{3,\ldots} Xn)$ i.e.

$Y = a + b_2X_2 + b_3X_3 + b_4X_4 + \ldots\ldots + bnXn.$

Here Y is dependent upon values assigned to different variables X_2, X_3, ... Xn. The term ‘a’ is a constant and b2, b3......bn are regression Coefficients and the subscripts indicate for the corresponding independent variables.

APPLICATION OF THE THEORY OF MULTIPLE LINEAR REGRESSION:

The dam may be an artificial structure impounding water in the reservoir, but it is a hydrologic phenomenon with inflows, storage and outflows. There is no reason not to believe that this phenomenon will behave like any other natural phenomena which change over space and time due to multiple causative factors.

This correlation concept has been established in the problem. The outflow (draft or release) from the reservoir is considered as function of inflows and the storage in time and space. Although several variables associated in a water resource system pertaining to the reservoir operation problem interlink in complex phenomena, but the degree of association can be interrelated and analyzed with certain degree of accuracy, with the aid of adapted multiple regression technique.

SELECTION OF VARIABLES:

The criteria for selecting variables are subject to dispute. Complicated methods may be there for selecting variables but each my produce varying results. There may be reasons for attempting to reduce or increase the number of variables depending upon the values of correlation coefficients in different cases. It may happen that one of the independent variables does not appear to bear a significant relationship with the dependent variable after a regression equation is derived. The regression on the remaining variables can be tried and if better correlation coefficient is obtained then the additional variables considered earlier may be dropped for formation of the regression equations.

FORMULATION OF MULTIPLE LINEAR REGRESSED EQUATIONS USING LEAST SQUARE CRITERION

As stated earlier the multiple regression equation is of the form : $Y = f(X_2, X_3, ...Xn)$

or

$Y=a+b_2X_2 +b_3X_3 ....+bnXn$

A value of Y may be computed for the observed data such as X_1, X_2,... Xn in order to find out the constant ‘a’ and the regression parameters b_j(j = 2, 3,4....n). The values of constants may he found mathematically with the minimum deviation maintained between the estimated and observed values as a criterion.

Thus according to least square criterion the agreement between computed estimates Y and the observed value say X_1 is in harmony when the sum of the squares of the deviation between them is a minimum. In other words, when

$$\sum(X_1-Y)^2 = \sum(X_1-(a+b_2X_2 + b_3X_3 + \ldots ..bnXn) = \sum €^2$$
$$= \text{minimum}$$

Where, € is the deviation or the residual. It represents the difference of an observed value of the dependant variable from the predicted value by the estimated linear relationship. For a two variable 1inear relationship, the condition of least square criterion is satisfied by the following normal equation:

$$\sum(X_1) = a \bullet N + b\sum(X_2)$$
$$\sum(X_2X_1) = a \sum(X_2) + b\sum(X_2^2)$$

where, X_2 and X_1 represent the observed va1ues of the independent and dependent variables respective1y and N is the number of observations.

But incase of multiple linear regression to satisfy 1east-square criterion:

Suppose X_1 = observed dependent variable X_2, X_3, X_4...Xn are observed independent variab1es

i.e. $X_1 = f(X_2, X_3 \ldots ..Xn)$

Then least square criterion is satisfied for

$\sum(X_1-Y)^2$ = minimum = Z (say)

then , $dz/a=0, dz/b_2 = 0, dz/b_3 = 0, dz/b_4=0 \ldots\ldots , dz/bn=0$ etc.

X_1=Irrigation draft in i^{th} month

X_2=Initial storage of the reservoir in the i^{th} month

X_3=Inflow into the reservoir in the i^{th} month

(i)For the least square regression plane of X_1 on X_2 and X_3 with the equation of the form $X_1 = f(X_2, X_3)$

i.e.X_1=a + b_2X_2 + b_3X_3

the regression coefficients, the constant a, and the regression coefficients can be determined by solving the set of simultaneous normal equations as follows :

$\sum X_1 - (N.a + b_2\sum X_2 + b_3\sum X_3) = 0$

$\sum X_1X_2 - (a\sum X_2 + b_2\sum X_2^2 + b_3\sum X_2 X_3) = 0$

$\sum X_1X_3 — (a\sum X_3 + b_2\sum X_2 X_3 + b_3\sum X_3^2) = 0$

(ii) Similarly for a five variable case of multiple linear regression as used in the problem where $X_1 = f(X_2, X_3, X_4, X_5)$

i.e. $X_1 = a + b_2X_2 + b_3X_3 + b_4X_4 + b_5X_5$..,.

the final set of simultaneous normal equations satisfying the least square criterion are as follows:

$\sum X_1 -(N.a + b_2\sum X_2 + b_3\sum X_3 + b_4\sum X_4 + b_5\sum X_5) = 0$

$\sum X_1 X_2 - (a\sum X_2 + b_2 \sum X_2^2 + b_3\sum X_2 X_3 + b_4\sum X_2X_4 \div b_5\sum X_2X_5).= 0$

$\sum X_1 X_3 - (a\sum X_3 + b_2\sum X_2X_3 + b_3\sum X_3^2 + b_4\sum X_3X_4 + b_5\sum X_3X_5) =0$

$\sum X_1X_4 -(a\sum X_4 + b_2\sum X_2X_4 + b_3 \sum X_3X_4 + b_4\sum X_4^2 + b_5\sum X_4X_5) = 0$

$\sum X_1X_5 -(a \sum X_5 + b_2\sum X_2X_5 + b_3\sum X_3X_5 + b_4\sum X_4X_5 + b_5\sum X_5)=0$

the values regression constant a and coefficients b_2, b_3, $b_4$and b_5 can be determined by solving the above set of simultaneous equations.

Thus finally the forecasting equations :

$Y = a + b_2X_2 + b_3 X_3$ and

$Y = a + b_2X_2 + b_3X_3 + b_4X_4 + b_5X_5$

for three variables and five variables respectively can be made ready with the determined values of constants and coefficients a, b_2 , b_3 for the ‘first case, and a, b_2, b_3 ,b_4 and b_5 for the second case, from given observed values of X_1, X_2, X_3, X_4 and X_5.

MULTIPLE CORRELATION COEFFICIENT- (R)

The coefficient of multiple correlation is a measure of the strength of the relationship in the sample between independent and dependent variables. When a 1inear equation is used the coefficient of multiple correlation(regression) is called the coefficient of multiple linear correlation (or regression).

A value of R equal to zero indicates no relationships. A perfect relationship is considered when the value of R is one. A correlation coefficient of zero indicating no linear relationship.

In the case of three variables with one dependant and two independent variables the coefficient of correlation is computed from:

$$R_{1.23} = \{1-(S_{1.23}{}^2/S_1{}^2)\}^{0.5}$$

where $R_{1.23}$ is multiple correlation coefficient.

$S_{1.23}$ i.e. standard error of estimate of X_1 on X_2 and X_3 is again computed by

$$\mathbf{\{\sum(X_1-Y_{est})^2 /N\}^{0.5}}$$

where, Y_{est} is the estimated values of X_1 as calculated from the regression equations.

S_1 is the standard deviation of the variable X_1 given by

$$\mathbf{[\sum(X_1-X_{mean})^2 /N]^{0.5}}$$

Thus, $R_{1.23} = [1-\sum(X_1-Y_{est})^2 /\sum(X1-X_{mean})^2]^{0.5}$

Thus on extension to more number of independent variables the general expression for the multiple correlation coefficient,

$$R_{1.2345} = [1-S_{1.2345}{}^2/ S_1{}^2]^{0.5}$$

CHOICE OF MULTIPLE LINEAR REGRESSION :

There is popular choice for establishing a linear relationship among interdependent variables for the following reasons:

1. The problem is simpler and easy to work with
2. It is the first order approximation for a non—linear relationship
3. There is no reason not to believe that linear relationship does not exist.

Deviation from a perfect linear relationship can be thought of as due to the effects of other unspecified variable or due to complex interlinking or interaction, which cannot be taken care of fully due to some limitations or other.

DATA PROCESSING

4.1. GENERAL:

Correct and reliable hydrological data of a long record are very much useful for a water resource planner. In the problem as obtained from the project report of Uduthorehalla reservoir project (4.1), calculated stream flows of only twenty six years are available, basing on rainfall runoff regressed model. But the economical life of the reservoir is beyond that length of time which is supposed to be fifty years. The exact pattern of flows during this historical period is extremely unlikely to recur during that period in which the proposed reservoir will be operative. Further, the present values of high flows, low flows and other characteristics of record may not likely be maintained, during the economic life of the system. The worst flood or drought in the historical record as here to assumed may not be worst possible flood or drought (4.2). Another important fact is that in evaluating some methods, as some solutions to some hydrological problems, the historical record alone gives no idea of the risks involved. To avoid such a difficulty and dilemma, the water resource planner has depend on operational hydrology. Thanks to the hydrologists and meteorologists who have given new insights into the mechanism of stream flows. Now the planner is in a position to generate longer duration of storm flows which are neither actual historical records nor prediction of future flows. Those are only close enough to possible historical records retaining all the possible statistical properties. Such generated or synthesized stream flows are extremely useful as planning tools.

Modern electronic computers with fantastic speed of computation now come to the aid and make the field of operation hydrology more interesting. The generation of stream flow data for a desired longer duration which involve laborious process of computations can now easily be computed with the electronic process in the shortest possible time.

The planners are now in a position to get new insights into the most difficult problems by carrying on research with more zeal and vigour.

4.2. GENERATION OF DATA BY THOMAS AND FIERING MODEL APPROACH

The most appropriate practical model is proposed by Thomas and Fiering (4.3) particularly with respect to generating monthly sequential stream flows. The Markovian concept is involved in this approach.

The algorithm for the Thomas and Fiering seasonal model (4.3) is as follows:

$$Q_{i+1}=\underline{Q}_{j+1} + Bj(Q_i - \underline{Q}_j)+t_i\, S_{j+1}(l-r^2)^{1/2} \tag{4.1}$$

where, Q_{i+1}, Q_i are generated flows during the $(i+l)^{th}$, i^{th} seasons (months) reckoned from the start of the synthesized sequences.

$\underline{Q}_{j+1}$, $\underline{Q}_j$ are mean flows during $(j+1)^{th}$, j^{th} seasons (months) within a repetitive annual cycle of seasons. (if months are being used, then $1<=j<= 12$).

B_j is least square regression coefficient for estimating $(j+1)^{th}$ flow from the j^{th} and given by

$B_j = r_j*s_{j+1}/s_j$

t_i is normal random variate with zero mean and unit variance.

S_{j+l}, S_j = Standard deviations of flow during the $(j+1)^{th}$, j^{th} th seasons, and

r_j= correlation coefficient between flows in j^{th} and $(j+1)^{th}$

It shows that 36 parameters such as monthly means, standard deviations, and lag one serial correlations are required to use the model to generate monthly flows at a site. These are obtained from analysis of monthly historical flows.

The model is run in the following way,

Set $\underline{Q}_1 =\underline{Q}_{JAN}$ and successively Q_2, Q_3, Q_4.... are to be computed where t_i is the only unknown and in each step it is calculated as a Pseudo—random normal variate.

Now $Q_2= \underline{Q}_{FEB} + B_{FEB/JAN}(Q_1-\underline{Q}_{JAN})+t_1S_{FEB}(1-r^2_{FEB/JAN})^{1/2}$

$Q_3= \underline{Q}_{MAR} + B_{MAR/FEB}(Q_1-\underline{Q}_{FEB})+t_1S_{MAR}(1-r^2_{MAR/FEB})^{1/2}$

$Q_{13}=\underline{Q}_{JAN}+ B_{JAN/DEC}(Q_{12}-\underline{Q}_{DEC})+t_12S_{JAN}(1-r^2_{JAN/DEC})^{1/2}$

The above model is restricted to normally distributed flows. That is to say t_i is considered to be a normal random variate. The model is to be modified to suit to non—normal streams which is not discussed here.

PRACTICAL CONSIDERATIONS:

(i) Thus the model consists of two components:
a deterministic or correlation component $[\underline{Q}_{j+1}+B_j(Q_i-\underline{Q}_j)]$ and a random component $[t_i\, S_{j+1}(1-r^2_j)^{1/2}]$.The model is purely random if the first term is zero.
(ii)To use the model computation of mean, standard deviation and serial correlation of the historical flows are necessary.
Assume that the flows are normally distributed.
(iii) The normal random variate is generated by an appropriate routine which is available for all computers.
(iv) The model may generate negative flows. When this occurs, the negative value is used to calculate the next flow after which it is set to zero.

4.2.1. GENERATION OF RANDOM NUMBERS:

In generating the sequence of a given stream flows, it is generally considered that the flows are the outcome of a random process (4.2). The results of this process change with time involving probability. The probability is that high flows tend to follow high flows and similarly low flows tend to follow low flows. The sequence of past flows provides a clue to the probable future flows. Hence any model for generation of stream flows must include a random component in addition to a deterministic component, so as to reflect the sequences of future flows in the most possible way.

4.2.2. GENERATION OF RECTANGULARLY DISTRIBUTED NUMBERS

It is only possible to generate through computer the sequences of pseudorandom numbers, creful1y constructed to maintain the important properties of truely random numbers (4.2).The basic pseudo-random number generators first produce uniformly distributed numbers. Then other distributions are generated by 3uitable methods by using such numbers.

The sequential algorithm (4.4) for generating the uniformly distributed Pseudo—random numbers in the interval (0,1) is given by

$$r'_{i+1} = <10^P C r'_i> \qquad \text{... (4.2)}$$

where <a> denotes the fractional part of a, r'_{i+1} being the number at $(i+l)^{th}$ instant and r'_i at the i^{th} instant. 'p' is the number of digits in the pseudo—random number. 'C' is a constant multiplier, such that $0<C < 1$. The choice of C is as follows:

$$C = l0^{-p}(200 A \pm B)\ 10^{-p/2} \qquad \text{... (4.2b)}$$

where A is any non—negative integer and B is one of the numbers from the sequence 3,11,15,19,21,27,37,53,59, 67 ,69,77,83 or 91. The starting value of r should be $10^{-p}R$, where R´ is any integer not divisible by 2 or 5 and such that $0<R'<10^P$.

For example, suppose we choose p = 5, then

$$10^{-p}=10^{-s/2}=0.00316.$$

A possible choice for C is acquired by selecting

A =2, B =69, so that

$C = 10^{-5}$ (400—69) $=10^{-5}$ x 331= 0.00316

Similarly for selection of $r'_{0.}$

$r'_0 = 10^{-5}$ x R = 10^{-5} x 7= 0.00007.

Further values of r'_1 can be calculated sequentially using $r'_{i+1}=(10^5 x 10^{-5} x 331 x r_i)$..(4.2C)

4.2.3.GENERATION OF NORMALLY DISTRIBUTED RANDOM NUMBERS:

It is simple to generate normal random numbers from a sequence of unifomly distributed random numbers in the range (0,1). One method for transforming rectangular (0,1) deviates into normal (0,1) deviates is based on the use of the rectangularly distributed values (X'_1,X'_2) for such transformation the following relationships are used:

$$Y'_1=(-2 \log_e X'_1)^{1/2} \cos (2\Pi X'_2) \quad ...(4.3a)$$

$$Y'_2=(-2 \log_e X'_1)^{1/2} \sin (2\Pi X'_2) \quad ...(4.3b)$$

where Y'_1 and Y'_2 are normally and independently distributed in the interval (0,1). This transformation is due to Box and Muller.

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4.2.4. APPLICATION OF TF MODEL IN THE PROBLEM

The generated stream flows data using TF model (4.3) have been applied to the problem for analysis and study of reservoir operation. To generate rectangularly distributed Pseudo—random numbers and transform them into normally distributed random numbers in the interval (0,1), the equations (4.2c) and (4.3a) are respectively used.

The statistical properties like mean, standard deviation, correlation coefficient of the historical flows of twenty six years, are used in the model to generate flow for 50 years in natural series. A compact program of TF model including generation of random numbers and using thorn in the model simultaneously to give generated flow values in the natural series, is formulated. The program computes all the statistical properties required in the model including random variates and simultaneously generate the flow data.

The results of generated monthly stream flows in natural series of fifty years each are tabulated in Table 4.1 and 4,2 respectively. Their corresponding statistical properties such as mean, standard deviation, correlation coefficient are furnished in Table 4.3, 4.4, and 4.5 respectively. The statistical parameters as regards to mean, variance and standard deviation of the whole series of generated flows with respects to natural series are furnished in Table 4.6. It is indicated that these statistical parameters, so far as natural series of generated flows are concerned, remain very close to each other. In order to study the closeness of statistical parameters of generated flows such as the mean and standard deviation of monthly flow with identical parameters of historical flows, graphs are plotted. These graphs are shown in fig. 4.1(time vs monthly mean flows) and fig 4.2(time vs standard deviation of monthly flows).As indicated the closeness of statistical parameters are very much maintained for these sets of streamflows, historical as well as generated sequential flows in natural series.

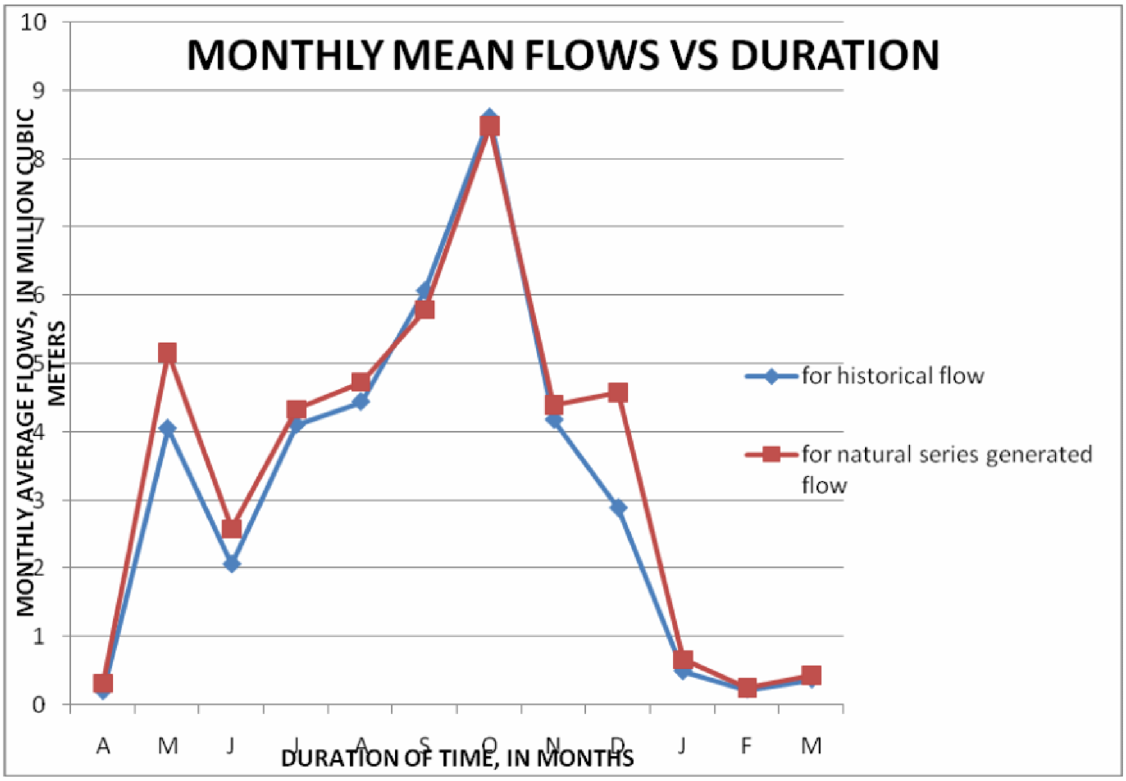


fig 4 .1.MONTHLY MEAN FLOW VS DURATION CURVE

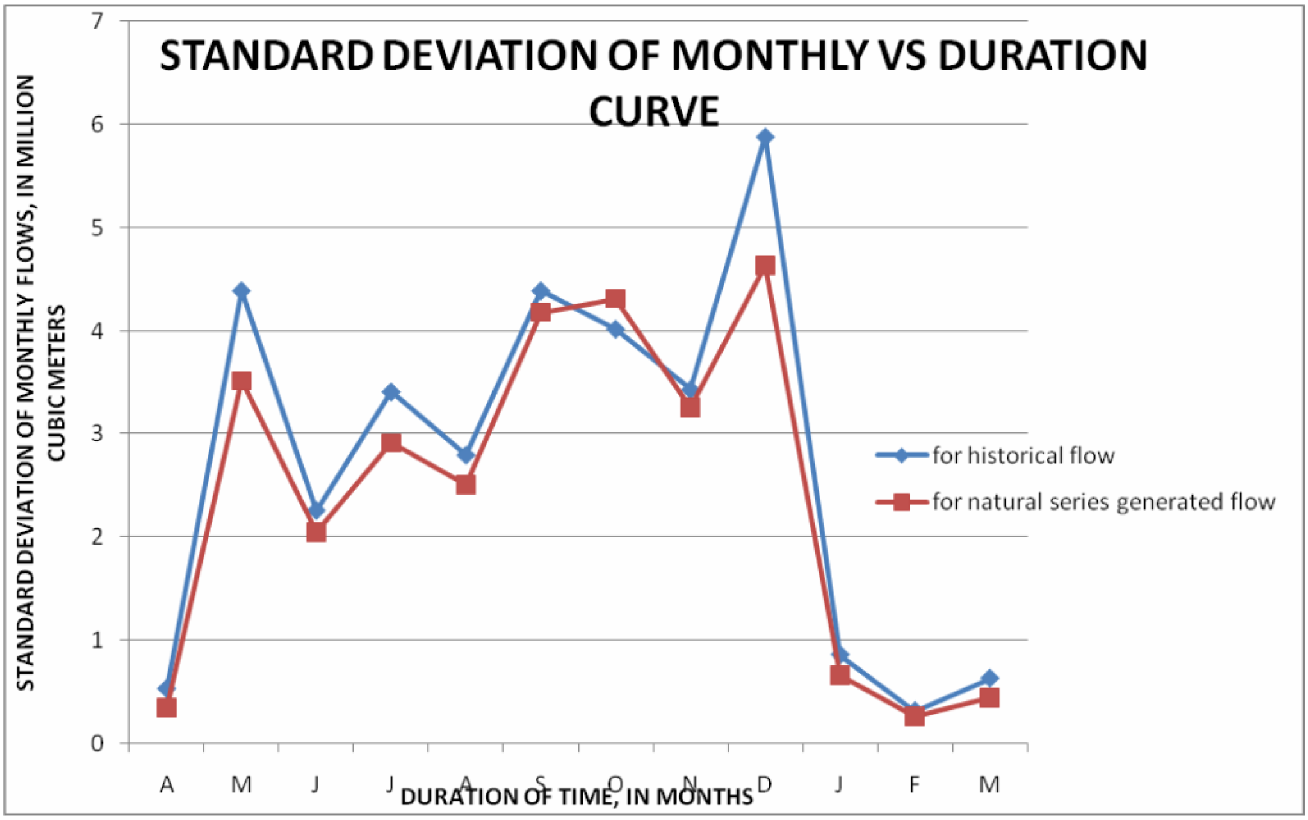


fig. 4.2.STANDARD DEVIATION OF MONTHLY FLOWS VS DURATION CURVE

COMPUTATIONS

5.1.FORMULATING MULTIPLE REGRESSED MONTHLY EQUATIONS AS OPERATION POLICY:-

The twenty six years of operation table given was considered for formulating the present monthly operation policy. The reservoir operating here starts from april and ends in march. The actual volume of water, available for drafts of irrigation for all these twenty six years in different months considering the corresponding years and months stream flows, storages and evaporation losses etc., were first determined. Thus for each month there are twenty six values of irrigation drafts (corresponding to twenty six years) which are functions of corresponding months storages and inflows.

All these monthly drafts (dependent variables) as actually possible for twenty six years of period and the corresponding stages of storages (independent variables) which are considered as the observed sequences for formulation of the forecasting equations for drafts, are furnished.

Thus the above flows and storages were obtained from the twenty six years of working and the corresponding drafts in particular months of the year were evaluated using the same working table based on simple operation rule where continuity equation is applied to the sequences of storages, inflows and outflows from the reservoir where evaporation is also considered. To make it more clear, if initial storage plus inflows minus the evaporation loss from the reservoir in a particular month equals or exceeds the corresponding monthly demand, then draft equal to full demand can be given in that month. If not, i.e. less, then that less amount itself will be the actual amount of draft possible in that month. These drafts in different time sequences in different months for entire twenty six years were noted. Thus this simple operation concept has been used here to evaluate the observed (actual) sequence of drafts which are the dependent variables considered here.

Thus now designating,

X_1=Irrigation draft in I th month

X_2= Initial storage of the reservoir in the I th month

X_3= Inflow into the reservoir in the I th month

Then the two cases of correlations are assumed

X_1= f (X_2, X_3)

Where X_2 and X_3 are dependent variables and X_1 is independent variable.

Then by considering all the twenty six observed equations corresponding to a given month and applying the principle of least –square criteria .,the forecasting equations for monthly drafts were evaluated. Thus for twelve months there are now twelve forecasting equations. To do this, the sets of simultaneous equations were solved. The constant 'a' and the regression coefficients $b_{1,}$ b_2 of the forecasting equation of the form:

$Y=a+b_2X_2+b_3X_3$ are now determined.

Thus for any given values of x2, x3, the forecasting value of Y can be easily computed. Here Y corresponds to the monthly forecasting drafts in the operation policy.

The twelve such monthly draft forecasting equations were formulated and there corresponding correlation coefficients were computed.

Similarly under the assumption of five variables correlated together in the second case, the multiple regressed monthly forecasting equations were evaluated by solving sets of simultaneous equations (3.11b) (3.11c), (3.11d), (3.11e) and (3.11f). Thus the values of the constant a and coefficients b_2, b_3,b_4 and b_5 of the monthly forecasting equation for draft of the form.

$Y = a + b_2X_2 + b_3X_3 + b_4X_4 + b_5X_5$ are determined. Thus for given values of X_2, X_3, X_4 and X_5 the forecasting draft Y can be easily computed.

The twelve such monthly draft forecasting equations under the assumption of five variables were evaluated. Their corresponding correlation coefficients were also computed using equation (3.20e). The equations are given in table 5.4.
Finally, based on the higher and suitable value of correlation coefficients of monthly equations in both the cases of multiple regression under three variables d five variables, the twelve multiple regressed monthly forecasting equations are selected depending on the criteria of higher and suitable value of correlation coefficients. These equations are given in table 5.5.

Since the dependent variables and independent variables were obtained originally in FPS units, the forecasting equations are also formulated in FPS units first and then they were converted to their MKS equivalents later on while using for reservoir operation.

5.2 RESERVOIR OPERATION:

The behavior of the uduthorehalla reservoir (5.1) is examined with regard to different combination of stream flows. The historical flows furnished in table 4,1 for a period of twenty six years are supposed to repeat in the hydrological cycle. This set of stream flows along with generated flows, in natural series as given in table 4.1 and 4.2, are used in the operation scheme separately.

To begin with a computer program for reservoir operation was formulated as furnished in Appendix — C. This program is aimed at finding out the behavior of the reservoir upon specific combinations of reservoir operation policy. In one subroutine subprogram (OPR) of the program simple operation policy is applied. This is the traditional method of operation technique — release all of the water demanded if available. The draft is independent of the reservoir content and season. If there is insufficient water in the reservoir to meet the target draft, the reservoir empties (5.4).

In the second subroutine subprogram (QPR) of the program the multiple regressed monthly operation policy is used. In this part the operation rule involves little restriction. Restrictions are imposed on the users, depending on the reservoir conditions and stream flows (5.4). The multiple regressed monthly operation policy determines directly the draft to be released depending upon the storages of the reservoir and the given values of stream flows. In case the draft determined by this policy exceeds the monthly demand, then it is restricted to the demand and usual operation is carried on for twenty six years with the historical flows or fifty years of flows of natural series as the case may be. The generated log series have not been considered in the problem for operation due to its wide variance in the statistical properties.

Another function subprogram to compute reservoir evaporation from computed values of area as a function of reservoir capacity from the given polynomial curve of equation 4.4 is also combined in the program.

Through the helps of the digital electronic computers the different computational works on reservoir operation are flow taken up. The desired information regarding the performance of the reservoir for the whole operative periods on different combinations of climatic as well as generated sequences of stream flows, is not available for detail scrutiny.

The performance of the multiple regressed model adopted here as a monthly operation policy is discussed in detail in the next chapter from the results obtained.

Table 5.1. MONTHLY IRRIGATION DRAFTS,

IN MILLION CUBIC METRES

SI NO.	YEAR	APRIL	MAY	JUNE	JULY	AUGUST	SEPTEMBER
1	1950-51	0.67944	0.5662	1.4155	1.52874	6.48299	4.38805
2	1951-52	2.06663	0.5662	1.4155	1.52874	6.48299	4.38805
3	1952-53	2.0663	0.5662	0.0000	0.73606	1.50043	2.06663
4	1953-54	0.8493	0.5662	1.4155	1.52874	6.48299	4.38805
5	1954-55	2.0663	0.5662	1.4155	1.52874	6.48299	4.38805
6	1955-56	2.0663	0.5662	1.4155	1.52874	6.48299	4.38805
7	1956-57	2.0663	0.5662	1.30226	1.52874	6.48299	4.38805
8	1957-58	2.0663	0.5662	1.4155	1.52874	6.48299	4.38805
9	1958-59	2.0663	0.5662	1.4155	1.52874	6.48299	4.38805
10	1959-60	2.0663	0.5662	1.4155	1.52874	6.48299	4.38805
11	1960-61	2.0663	0.5662	1.4155	1.52874	6.48299	4.38805
12	1961-62	2.0663	0.5662	1.4155	1.52874	6.48299	4.38805
13	1962-63	0.0000	0.5662	1.4155	1.52874	6.48299	4.38805
14	1963-64	2.0663	0.5662	1.4155	1.52874	6.48299	3.31227
15	1964-65	0.0000	0.5662	1.4155	1.52874	6.48299	4.38805
16	1965-66	2.0663	0.5662	1.4155	1.52874	6.48299	4.38805
17	1966-67	0.0000	0.5662	1.4155	1.52874	6.48299	4.38805
18	1967-68	2.0663	0.5662	1.4155	1.52874	6.48299	4.38805
19	1968-69	0.0000	0.5662	1.4155	1.52874	6.48299	4.38805
20	1969-70	2.0663	0.5662	1.4155	1.52874	6.48299	4.38805
21	1970-71	2.0663	0.5662	1.4155	1.52874	6.48299	4.38805
22	1971-72	2.0663	0.5662	1.4155	1.52874	6.48299	4.38805
23	1972-73	2.0663	0.5662	1.4155	1.52874	6.48299	4.38805
24	1973-74	2.0663	0.5662	1.4155	1.52874	6.48299	4.38805
25	1974-75	2.0663	0.5662	1.4155	1.52874	6.48299	4.38805

26	1975-76	0.0000	0.5662	1.30226	1.52874	2.83100	4.38805

MONTHLY IRRIGATION DRAFTS,

IN MILLION CUBIC METRES

SI NO.	YEAR	OCT	NOV	DEC	JAN	FEB	MAR
1	1950-51	2.17987	5.32228	2.85931	2.17987	2.17987	2.15156
2	1951-52	2.17987	5.32228	2.85931	2.17987	2.17987	2.15156
3	1952-53	2.17987	0.70775	2.85931	2.17987	1.72691	0.00000
4	1953-54	2.17987	5.32228	2.85931	2.17987	2.17987	2.15156
5	1954-55	2.17987	5.32228	2.85931	2.17987	2.17987	2.15156
6	1955-56	2.17987	5.32228	2.85931	2.17987	2.17987	2.15156
7	1956-57	2.17987	5.32228	2.85931	2.17987	2.17987	2.15156
8	1957-58	2.17987	5.32228	2.85931	2.17987	2.17987	2.15156
9	1958-59	2.17987	5.32228	2.85931	2.17987	2.17987	2.15156
10	1959-60	2.17987	5.32228	2.85931	2.17987	2.17987	2.15156
11	1960-61	2.17987	5.32228	2.85931	2.17987	2.17987	2.15156
12	1961-62	2.17987	5.32228	2.85931	1.50043	0.36803	0.28310
13	1962-63	2.17987	5.32228	2.85931	1.17987	2.17987	2.15156
14	1963-64	2.17987	5.32228	2.85931	1.17987	1.50043	0.00000
15	1964-65	2.17987	5.32228	2.85931	1.17987	2.17987	2.15156
16	1965-66	2.17987	4.75608	2.66114	0.0000	0.00000	0.00000
17	1966-67	2.17987	5.32228	2.85931	2.17987	2.17987	2.15156
18	1967-68	2.17987	5.32228	2.09494	0.0000	0.00000	0.00000
19	1968-69	2.17987	5.32228	2.85931	2.17987	2.17987	2.15156
20	1969-70	2.17987	5.32228	2.85931	2.17987	2.17987	2.15156
21	1970-71	2.17987	5.32228	2.85931	2.17987	2.17987	2.15156
22	1971-72	2.17987	5.32228	2.85931	2.17987	2.17987	2.15156
23	1972-73	2.17987	5.32228	2.85931	2.17987	2.17987	2.15156
24	1973-74	2.17987	5.32228	2.85931	2.17987	2.17987	2.15156
25	1974-75	2.17987	5.32228	2.85931	2.17987	1.13240	0.00000

26	1975-76	2.17987	5.32228	2.85931	2.17987	0.62282	0.00000

Table 5.2.RESERVOIR STORAGES IN THE BEGINNING OF MONTHS, in million cubic metres.

SI NO.	YEAR	APRIL	MAY	JUNE	JULY	AUGUST	SEPTEMBER
1	1950-51	4.986	4.16	9.34	7.93	7.106	9.427
2	51-52	7.814	6.341	13.702	14.589	17.779	13.532
3	52-53	7.247	5.01	4.275	4.16	4.16	4.16
4	53-54	14.579	4.160	16.93	21.23	21.23	15.967
5	54-55	10.645	12.286	13.476	13.391	15.85	16.420
6	55-56	7.558	8.379	13.872	16.335	16.987	13.985
7	56-57	12.739	5.322	4.856	4.16	8.66	5.771
8	57-58	12.824	10.446	20.921	21.23	21.23	18.033
9	58-59	12.399	10.531	14.127	15.712	19.845	20.496
10	59-60	9.795	10.106	13.985	20.949	21.23	21.23
11	60-61	15.202	7.530	6.66	7.36	20.723	21.23
12	61-62	4.160	12.881	12.060	14.749	15.250	10.41
13	62-63	8.974	4.161	21.232	21.23	21.23	21.23
14	63-64	8.974	6.738	7.587	7.246	7.756	5.233
15	64-65	4.16	4.16	7.587	7.247	16.696	10.784
16	65-66	12.258	9.965	9.625	8.323	8.578	7.303
17	66-67	4.16	4.16	6.907	5.718	14.099	9.17
18	67-68	14.579	12.286	11.465	12.287	15.062	9.31
19	68-69	4.16	4.16	8.182	8.097	6.545	4.16
20	69-70	6.624	4.416	6.964	5.746	7.004	9.682
21	70-71	9.03	6.795	6.313	9.74	7.926	5.832
22	71-72	9.908	7.95	9.738	8.748	7.983	8.436
23	72-73	16.788	17.014	17.976	17.127	18.259	13.051
24	73-74	18.118	16.306	19.706	20.694	21.23	21.204
25	74-75	9.880	7.615	8.504	9.795	11.459	8.804
26	75-76	4.16	4.16	5.359	4.16	4.388	4.16

RESERVOIR STORAGES IN THE BEGINNING OF MONTHS, in million cubicmetres.

SI NO.	YEAR	OCTOBER	NOV	DEC	JAN	FEB	MARCH
1	1950-51	21.23	21.23	16.193	13.221	11.097	8.832
2	51-52	12.541	15.853	17.071	14.098	11.805	9.540
3	52-53	4.16	4.926	4.162	8.096	5.832	4.16
4	53-54	17.807	21.23	20.808	18.091	16.244	13.956
5	54-55	12.484	21.23	15.797	16.307	14.692	12.852
6	55-56	11.465	19.590	15.344	14.409	12.116	9.852
7	56-57	5.322	21.23	21.23	19.251	16.958	14.664
8	57-58	19.590	21.23	21.23	18.317	16.080	13.844
9	58-59	21.23	21.23	21.23	18.232	16.221	14.749
10	59-60	21.23	21.23	18.486	16.448	14.155	11.862
11	60-61	21.23	21.23	21.23	18.996	19.053	17.467
12	61-62	7.53	21.23	8.465	5.718	4.16	4.16
13	62-63	21.23	12.739	16.533	15.882	13.588	11.296
14	63-64	4.16	21.23	8.606	7.983	5.718	4.16
15	64-65	13.023	7.672	20.921	19.194	16.901	14.607
16	65-66	6.086	21.23	4.16	4.16	4.16	4.16
17	66-67	15.231	8.493	21.23	18.883	18.712	16.419
18	67-68	4.812	15.31	4.359	4.16	4.16	4.16
19	68-69	10.673	13.475	15.202	13.476	11.182	8.919
20	69-70	7.643	14.239	13.221	15.146	13.192	10.899
21	70-71	4.784	21.23	14.665	14.523	13.136	11.607
22	71-72	18.798	17.693	21.23	21.23	20.326	18.769
23	72-73	11.465	21.693	15.571	21.23	21.23	19.876
24	73-74	21.23	14.579	17.608	15.712	13.928	11.975
25	74-75	14.523	9.767	10.106	7.162	4.897	4.16
26	75-76	7.756	7.170	8.917	6.694	4.727	4.16

Table 5.3.(i)EQUATIONS REPRESENTING MONTHLY OPERATION RULES (USING 3 VARIABLES)

MONTH	MULTIPLE REGRESSED EQUATIONS CONSIDERING THREE VARIABLES	MULTIPLE CORRELATION CO-EFFICIENT
April	$Y=0.3291569 + 0.13338X_2 - 0.13176X_3$	0.7390137
May	$Y=0.5662 + 0.X_2 + 0.X_3$	-
June	$Y=1.1584806+0.0156809X_2+0.00870589X_3$	0.3066569
July	$Y=1.3681544+0.0073769X_2 + 0.0108123X_3$	0.3425904
August	$Y=4.051016 + 0.1066893X_2 + 0.1185531X_3$	0.5236255
September	$Y=3.7591124 + 0.0284964X_2+0.0263215X_3$	0.416700
October	$Y=2.17987+ 0.X_2 + 0.X_3$	-
November	$Y=3.7474399 + 0.0627707X_2+0.0775105X_3$	0.4803952
December	$Y=2.623698 + 0.0127707X_2+0.00182488X_3$	0.4780503
January	$Y=0.9326864+0.0788501X_2 - 0.1184354X_3$	0.6303137
February	$Y=0.4348076 + 0.1163X_2 - 0.3806X_3$	0.8187795
March	$Y=0.1495249 + 0.156X_2 + 0.1026X_3$	0.8327677

Table 5.3(ii)EQUATION REPRESENTING THE MONTHLY OPERATING RULES(USING 5 VARIABLES)

MONTH	MULTIPLE REGRESSED EQUATION (CONSIDERING 5 VARIABLES)	MULTIPLE LINEAR CORELATION COFFICIENT
April	Y=0.17645+0.11760X2-0.19102X3+0.02983X4+0X05	0.75498
May	Y=0.56620+0.X2+0.X3+0.X4+0.X5	-
June	Y=1.62596+0.50521X2-0.02105X3-052876X4-0.5X5	-
July	Y=1.36812+0.00676X2+0.01001X3+0.00125X4-0.00171X5	-
August	Y=4.04037+0.14921X2+0.12322X3-0.05133X4-0.X5	0.60743
Sept	Y=2.95021+0.14546X2-0.022429X3-0.03004X4-0.03216X5	-
Oct	Y=2.17552-0.00003X2+0.00053X3+0.00002X4+0.X5	-
Nov	Y=3.07068+0.27456X2-0.04065X3-0.18752X4+0.X5	-
Dec	Y=2.61849+0.01429X2+0.00118X3+0.00001X4-0.00425X5	0.48454
Jan	Y=093281X1+0.07159X2-0.10964X3+0.0065X4-0.00011X5.	0.63094
Feb	Y=-0.08339X1+0.022657X2+0.00005X3+ 0.12193X4- 0.24228X5	0.878465
Mar	Y=0.19349X1+0.22080X2+0.00132X3-0.03365X4-0.83330X5	0.85877

ANALYSIS OF RESULTS, DISCUSSIONS, CONCLUSIONS AND SUGGEST IONS

6.1. RESERVOIR PERFORMANCE DURING OPERATION PERIOD:

Desired information, regarding the reservoir behavior during the operative periods on specific reservoir operation techniques followed in the present work, are obtained.

(A) i. The monthly irrigation drafts during the operative period.

ii. The monthly reservoir storages during the reservoir operation.

iii. The number of time the storage remains less than maximum capacity during operation.

iv. The no. of times the reservoir spills during operative period.

v. The number of times the reservoir in emptied throughout the operation period.

vi. The number of times there is irrigation deficit during operation.

vii. The volume of average annual irrigation deficiency in million cubic meters.

viii. The volumeof average annual spill in million cubic meters.

ix. The irrigation shortage Index due to operation policy.

x. The number of times of irrigation deficiency in a particular month of the whole operation period.

xi. The average monthly irrigation deficiency in million cubic meters.

xii. The number of times the reservoir spill, in a particular month.

xiii. The volume of average monthly spill in million cubic meters.

With additional computations the following information are also obtained refer Chapter 3.

(B) i. The probability of failure (P_e) duo to operation policy.

ii. The reliability (R_e) of the reservoir due to corresponding operation policy.

iii. The Volumetric Reliability (R_v) of the reservoir to same adopted operation policies.

These information of reservoir behavior during the whole operative period as listed above are tabulated in the table numbers from 6.1 to 6.8 which are self explanatory, give clues on the effectiveness of the multiple regressed operation technique.

Table.6.1.OPERATION ON NATURAL SERIES IRRIGATION DRAFTS'

IN MILLION CUBIC METRES.

YR	APR	MAY	JUN	JUL	AUG	SEPT
1	0.84723	0.56620	1.39944	1.53272	6.49740	4.39824
2	1.8O43	0.56620	1.36929	1.51498	6.49740	4.39824
3	2.06584	0.56620	1.39944	1.53272	6.49740	4.39824
4	2.06584	0.56620	1.39980	1.49961	6.06649	4.19757
5	2.065	0.56620	1.39944	1.53272	6.49740	4.39824
6	1.743	0.56620	1.35318	1.44909	5.33702	4.23468
7	1.71891	0.56620	1.39944	1.52902	6.49740	4.39824
8	1.78622	0.56620	1.32587	1.51306	6.35996	4.29932
9	1.84217	0.56620	1.29067	1.49053	6.15281	4.11804
10	1.38709	0.56620	1.33720	1.52586	6.09010	4.20201
11	2.06584	0.56620	1.39944	1.52371	6.36301	4.18106
12	1.78604	0.56620	1.35069	1.49554	6.42785	4.39824
13	1.47220	0.56620	1.30055	1.43014	3.30605	0.00000
14	2.06584	0.56620	1.39944	1.53272	6.15811	4.20515
15	1.96261	0.56620	1.39944	1.53272	6.26255	4.17963
16	0.94468	0.56620	1.32354	1.48062	6.09132	4.39824
17	2.06584	0.5662O	1.39944	1.53272	6.49740	4.19713
18	1.81091	0.56620	1.35285	1.53272	6.49740	4.29403
19	1.47057	0.56620	1.39944	1.48163	5.71905	4.04842
20	2.06584	0.56620	1.39944	1.53272	6.17826	4.39448
21	1.89898	0.56620	1.39944	1.49702	6.10882	4.20771
22	1.46480	0.56620	1.38964	1.52856	6.49740	4.38835
23	2.06584	0.56620	1.39944	1.53272	6.49740	4.30648

24	2.05584	0.56620	1.39944	1.52252	6.24668	4.39824
25	2.06584	0.56620	1.39944	1.53272	6.49740	4.39824

YR	APR	MAY	JUN	JUL	AUG	SEPT
26	1.36386	0.56620	1.39944	1.53272	6.49740	4.36066
27	2.06584	0.55620	1.37874	1.46361	6.43106	4.36773
28	1.69529	0.56620	1.39944	1.53272	6.49740	4.39824
29	2.06584	0.56620	1.39944	1.53272	6.49740	4.39824
30	2.06584	0.56620	1.39944	1.53272	6.40698	4.32821
31	2.06584	0.56620	1.39944	1.53272	6.49740	4.39824
32	2.02505	0.5662O	1.39944	1.52477	6.49740	4.39824
33	1.74437	0.55620	1.37343	1.50003	5.95086	4.23881
34	2.06584	0.56620	1.39944	1.53272	6.11825	4.18550
35	0.89284	0.56620	1.23917	1.43866	3.86164	4.02808
36	1.18920	0.56620	1.32716	1.50968	6.49740	4.39824
37	1.94020	0.56620	1.39944	1.53272	6.49740	4.39824
38	2.06584	0.56620	1.39944	1.53272	6.49740	4.35911
39	1.87559	0.56620	1.29371	1.47503	5.67012	4.19462
40	1.42099	0.56620	1.31508	1.47072	5.43330	4.09896
41	l.45610	0.56620	1.39944	1.53066	5.40771	4.39824
42	2.05068	0.56620	1.39944	1.47708	6.05826	4.34155
43	2.05584	0.56620	1.39944	1.52272	6.49740	4.39824
44	2.06584	0.56620	1.39944	1.53272	6.44013	4.32604
45	2.06584	0.56620	1.39944	1.52272	6.49740	4.39824
46	1.42583	0.56620	1.35097	1.51636	6.49740	4.39824
47	2.06584	0.56620	1.36009	1.48795	6.38900	4.39824

48	2.06584	0.56620	1.39711	1.52963	6.33432	4.26435
49	2.06584	0.56620	1.39940	1.49209	6.1t168	4.39824
50	2.06584	0.56620	1.39944	1.51116	6.17413	4.39707

YR	OCT	NOV	DEC	JAN	FEB	MAR
1	2.16580	5.33120	2.86552	2.16580	2.16580	2.16580
2	2.16580	5.3312O	2.86552	2.16580	2.16580	2.16560
3	2.16580	5.28174	2.86552	2.16583	2.16580	2.16580
4	2.16580	5.01087	2.82226	2.16580	2.16580	2.16580
5	2.16580	5.33120	2.86552	2.16560	2.16580	2.16580
6	2.16580	4.44962	2.72197	1.53045	1.00514	1.42853
7	2.16580	5.08006	2.85046	2.08224	1.96022	1.81012
8	2.16580	5.08501	2.81076	2.08851	2.00940	2.01090
9	2.16580	4.29109	2.69150	1.73654	1.44514	1.17947
10	2.16580	5.33120	2.86552	2.16580	2.16580	2.12396
11	2.16580	5.33120	2.86552	2.16580	2.16580	2.03434
12	2.16580	5.08006	2.84724	1.89017	1.59616	1.58689
13	2.16580	5.33120	2.84716	2.16580	2.16580	2.16580
14	2.16580	5.33120	2.86552	2.16580	2.16580	2.16580
15	2.16580	4.39454	2.08188	1.92132	0.07774	0.69647
16	2.16580	5.33120	2.86552	2.13988	2.16580	2.04146
17	2.16580	5.10804	2.84366	2.16580	2.16580	1.99059
18	2.16580	5.12458	2.83045	2.08911	1.66000	1.56405
19	2.16580	5.04291	2.81711	2.16580	2.11593	2.10121
20	2.16580	5.23588	2.86552	2.16580	2.16580	2.16580
21	2.16580	5.33120	2.82253	2.16580	1.97248	1.56883

22	2.16580	5.33120	2.86552	2.05120	2.16580	2.16580
23	2.16580	5.33120	2.86552	2.16580	2.16580	2.16580
24	2.16580	5.33120	2.86552	2.16580	2.10580	2.16580
25	2.16580	5.16808	2.85723	2.16580	1.90277	1.59489

YR	OCT	NOV	DEC	JAN	FEB	MAR
26	2.16580	5.19112	2.86552	2.16580	2.16580	2.16580
27	2.16580	4.86278	2.80164	2.08157	2.02551	2.11741
28	2.16580	5.29383	2.86552	2.16580	2.16580	2.16580
29	2.16580	5.33120	2.86552	2.16580	2.16580	2.16580
30	2.16580	5.33120	2.86552	2.16580	2.16580	2.16580
31	2.16580	5.33120	2.86552	2.16580	2.16580	2.16560
32	2.16580	5.33120	2.86552	2.16580	2.16580	1.68019
33	2.16580	4.90866	2.80887	2.16560	2.16580	2.16580
34	2.16580	4.67909	2.76380	1.61155	1.11724	0.70550
35	2.16580	4.97043	2.81301	1.82079	1.48220	1.09339
36	2.16580	5.33120	2.86552	2.16580	2.16580	2.16580
37	2.16580	5.28289	2.86552	2.16580	2.16580	2.16580
38	2.16580	5.33120	2.86552	2.16580	2.16580	2.16580
39	2.16580	4.93263	2.78348	1.96472	1.78817	1.51669
40	2.16580	5.01284	2.82950	2.10421	2.03893	1.59200
41	2.16580	5.33120	2.86552	2.16530	2.16580	2.16580
42	2.16580	5.28466	2.86552	2.16580	2.16580	2.16580
43	2.16580	5.10157	2.86509	2.16580	2.16580	2.16580
44	2.16580	5.33120	2.86552	2.16580	2.16580	2.16580
45	2.16580	5.08006	2.84724	1.92701	1.67034	1.35882

46	2.16580	5.33120	2.86552	2.16580	2.16580	2.16580
47	2.16580	5.33120	2.86552	2.16580	2.16580	2.16580
48	2.16580	5.06897	2.84236	2.16580	2.16580	2.16580
49	2.16580	5.33120	2.86552	2.16581	2.16580	2.16580
50	2.16580	5.33120	2.86552	2.16580	2.16580	2.16580

Table 6.2.OPERATION ON NATURAL SERIES MONTHLY STORAGES' IN MILLION CUBIC METRES

YR	APR	MAY	JUN	JUL	AUG	SEPT
1	4.18326	19.10950	21.23000	21.23000	20.01007	21.23O00
2	10.58028	11.86278	13.15406	16.06721	15.35718	19.57848
3	14.69532	20.47823	21.23000	21.23000	21.23000	21.23000
4	14.98586	14.15041	13.67492	14.83448	12.75827	11.24149
5	15.80954	16.79861	20.27402	21.23000	20.94476	20.01421
6	9.84365	12.31070	10.97113	9.37694	9.04167	12.91190
7	8.80714	18.02831	21.23000	19.87921	19.51459	20.86978
8	9.30537	9.59716	10.04049	14.90943	13.30849	14.93405
9	8.98229	8.19130	7.17563	11.95175	11.28365	8.43377
10	7.06486	10.15069	10.88326	16.33S31	11.45583	11.51214
11	11.08767	15.57679	14.89257	17.40778	14.80694	10.46512

12	8.47098	11.28465	11.50723	13.77881	14.62500	19.02562
13	6.76600	9.07905	7.62019	6.59436	4.16000	4.16000
14	11.96668	16.27652	18.27539	20.46573	14.12430	11.40839
15	11.1425	16.79011	18.41891	21.23000	11.99842	10.41682
16	4.22260	9.39399	9.93865	11.92359	15.37087	20.56018
17	10.72972	12.51052	13.86583	20.17844	18.77130	11.02043
18	8.81000	16.24643	16.31372	21.23000	10.15233	14.29266
19	6.77897	10.66211	12.24853	12.74626	15.32180	5.96266
20	10.41290	17.31094	21.23300	21.23000	14.15602	18.24358
21	11.35865	16.0610O	16.70708	15.55610	18.64604	11.49983
22	7.64947	16.97757	18.23625	18.89841	18.04073	17.75015
23	13.26784	14.74139	13.16453	19.04395	15.63918	14.80903
24	16.64465	21.23000	19.59554	18.77856	21.23000	21.23000
25	14.33411	19.18542	19.08144	21.23000	20.01007	21.23000

YR	APR	MAY	JUN	JUL	AUG	SEPT
26	6.94967	16.45438	19.25369	21.23000	20.66196	16.57654
27	14.30567	13.47509	12.93986	11.32308	15.74638	17.23518
28	9.80166	17.54959	16.93861	20.31114	17.74609	21.23000
29	13.40542	21.23000	21.23000	21.23000	20.76422	21.23000
30	13.80921	21.23000	21.23000	21.23000	16.91908	15.69639
31	12.44232	14.09201	16.81380	21.23000	18.52164	18.80835
32	10.25728	16.47452	21.23000	19.49476	20.41884	21.2300o
33	8.37076	12.37849	13.21252	14.72674	11.77434	12.83926
34	14.80208	21.23000	21.23000	21.23000	14.90131	10.62093
35	5.35672	4.61701	4.20656	9.29199	4.16000	5.70675

36	5.27330	10.13172	9.78058	14.51362	15.72281	21.23000
37	9.37250	16.87692	15.68870	20.25549	17.61186	19.72186
38	13.48665	18.69223	20.16354	21.23000	18.22081	26.71904
39	9.41928	8.62408	7.17551	10.53953	8.16539	11.51063
40	6.56508	9.98703	8.50812	10.56864	7.03828	8.08024
41	8.55072	19.77487	21.23000	20.02696	17.17308	19.10828
42	10.38338	14.23760	14.70601	13.12834	13.50716	16.46238
43	12.91201	12. 56437	17.4377	19.60434	19.35561	21.23000
44	14.07764	17.52663	21.13017	21.3200	17.10907	15.60147
45	14.07765	19.63203	21.23000	21.23000	21.12401	21.23000
46	8.96848	12.27557	10.7497	15.43326	16.15623	21.23000
47	12.40439	12.33589	11.73457	13.15939	14.57509	20.00279
48	14.25339	14.28414	14.37543	17.78102	l4.3152d	13.56907
49	13.31211	18.141219	16.80075	15.13787	14.79305	21.23000
50	12.45094	14.88857	19.25369	17.68394	15.27260	18.34174

YR	OCT	NOV	DEC	JAN	FEB	MAR
1	21.23000	21.11093	18.10614	15.82076	l3.54464	11.77281
2	21.23000	21.23000	21.23000	21.22849	19.40706	17.01930
3	18.88885	17.94260	21.23000	20.52892	18.41701	16.61559
4	16.41962	14.28476	21.23000	20.50221	19.03432	17.08768
5	2l.23000	20.95280	17.94934	15.66472	13.43573	11.08897
6	11.18651	6.63953	11.09961	11.64882	11.05871	10.57839
7	21.23000	16.00964	15.76477	14.32604	12.59364	11.00092
8	14.37540	14.77470	16.09282	14.72847	12.75089	11.00019
9	8.66089	4.28122	11.49835	10.08329	8.82951	8.42438

10	17.0823	21.23000	18.22420	17.05928	15.38175	13.06720
11	18.58141	20.14819	17.15089	14.86983	12.68309	10.47124
12	21.23000	16.00964	13.05145	11.79627	10.18722	8.43534
13	13.96456	17.70122	21.23000	18.92390	16.63417	14.27025
14	21.23000	20.70723	17.70573	15.81882	13.67991	12.64110
15	8.13225	5.40722	4.16000	4.91511	4.77150	5.32285
16	21.23000	21.23000	18.22420	16.15610	14.34505	12.99723
17	19.43677	16.00148	16.62277	14.34380	12.07215	10.83767
18	17.69139	15.86742	13.22949	11.76648	10.09901	8.44565
19	15.85788	14.55730	17.58791	16.65572	14.96266	12.67309
20	21.23000	17.84361	18.31728	16.79097	14.76392	12.50501
21	12.16066	17.50192	14.56263	12.36705	10.44805	8.93344
22	21.23000	20.87099	21.23000	19.47493	17.59334	15.58014
23	21.23000	21.23000	21.23000	20.84253	19.49455	17.71144
24	21.23000	21.23000	21.23000	19.44962	17.15672	16.23448
25	21.23000	17.04642	14.07435	11.91805	9.91588	8.15759

YR	OCT	NOV	DEC	JAN	FEB	MAR
26	21.23000	17.31750	21.23000	20.14540	18.25812	16.62617
27	16.53111	12.55355	16.43175	15.22260	13.15733	10.90005
28	21.23000	18.52400	21.23000	19.74437	17.97011	15.59619
29	21.23000	21.23000	21.23000	19.57245	17.34509	15.57752
30	19.19464	21.23000	21.21373	19.03764	16.74725	14.38257
31	21.23000	21.23000	18.22420	16.01567	13.88597	12.39110
32	21.23000	19.30461	16.31290	14.03507	11.84931	10.32832
33	14.83113	12.77531	21.23000	20.84660	19.51602	17.127O6

34	14.84209	10.05573	8.56998	6.87024	5.87330	5.72907
35	17.68784	14.04634	11.12830	9.21032	7.78290	6.63552
36	21.23000	21.23000	18.22420	15.93822	13.66171	11.53399
37	21.23000	18.39558	20.20851	19.02960	17.14995	15.79947
38	21.23000	21.23000	18.22420	15.93822	13.66171	11.31390
39	12.89965	12.69334	13.36482	11.36048	9.47445	8.18061
40	18.97304	14.79047	15.02475	12.81273	10.89994	9.41843
41	21.23000	21.23000	l8.22420	17.11166	14.83077	12.47729
42	21.23000	18.41646	20.6324	18.69193	16.55026	15.22179
43	21.23000	16.26321	21.23000	19.29620	17.13406	15.78389
44	20.06355	19.19768	21.23000	19.70158	17.83723	15.88727
45	21.23000	16.00964	13.05145	11.41826	9.96829	9.65196
46	21.23000	19.98834	21.23000	18.92838	16.78287	14.57894
47	21.23000	21.23000	21.23000	19.83940	18.27846	15.98822
48	18.84561	15.42915	21.23000	19.85860	17.69312	15.32146
49	21.23000	21.23000	19.35735	18.28506	16.60855	14.24480
50	21.23000	20.33269	21.23000	19.07140	16.98045	15.44271

Table 6.3.50 YEARS OF RESERVOIR OPERATION
(WITH GENERATED RAINFALL FLOW)

SI NO.	PARTICULARS	APR	MAY	JUN	JUL	AUG	SEP
1	Monthly irrigation demand	2.07	0.57	1.42	1.53	6.48	4.39
2	No. of monthly irrigation demand	27	50	21	29	29	29
3	Avg. monthly irrigation demand	0.25514	0.00024	0.02378	0.02079	0.30997	0.17208
4	No. of monthly reservoir spills	0	4	10	15	2	12
5	Avg. monthly spills	0.0	0.10780	0.26320	1.04915	0.07521	0.67675

SI NO.	PARTICULARS	OCT	NOV	DEC	JAN	FEB	MAR
1	Monthly irrigation demand	2.18	5.32	2.85	2.18	2.18	2.15
2	No. of monthly irrigation demand	0	26	22	16	16	21
3	Avg. monthly irrigation demand	0.0	0.17178	0.03683	0.09109	0.17531	0.22972
4	No. of monthly reservoir spills	28	13	17	0	0	0
5	Avg. monthly spills	3.22649	0.53414	1.29492	0.0	0.0	0.0

Table 6.4.Results of Reservoir Operations

SI NO.	PARTICULARS	50 YRS OF OPERATION WITH GENERATED FLOW
1	Probability of Failure(Pe)	0.00 (0%)
2	Reliability (Re)	1 (100%)
3	Volumetric Reliability(Rv)	0.9553 (95.53)

6.2. ANALYSIS OF RESULTS AND DISCUSSIONS:

The volume of storages, table Nos. from 6.1 to 6.3 that would be retained in the reservoir at the end of every month during the whole operation period were classified into nine classes in between the range from the dead storage to maximum capacity at the class interval of two million cubic meters. In each class of the range the appropriate storages were included and the cumulative probability i.e. the probability that the random variable has a value equal to or less than certain assigned value , P(X<=x) was calculated for each class interval of storages. These are tabulated in tables 6.9 to 6.11. the same were represented graphically in fig. 6.1. and fig 6.2 by plotting average storage values of each class interval against duration curves.

From these graphs it is evident that the probability, that the storage is equal or less than a given value, is always less than a given value , is always less in case of the reservoir operation with multiple regressed monthly equations than the simple case of operation i.e. without adopting the equations. It is indicated that relatively higher storages are always maintained in the reservoir operated with equations. Less scopes are given for the reservoir to fall down to lower volumes of storages in this case.

(ii) (a) It is indicated from the operational results furnished in table 6.4 that the average annual deficiencies in both cases of operation remain close to each other. But the amount of deficiency faced in each time is likely to be much reduced in case of multiple regressed operation policy than the simple one due to the fact that the number of deficiency faced during the whole operative period is far larger in the former case than the later one.

Further there is a difference of only 2 percent in average annual deficiencies among both the cases of operation. Considering the case of operation with natural series as the most realistic one, one finds that the average annual deficiency is only 4.46 percent of annual irrigation demand which may be permissible and satisfactory.

(b) Similarly also the average annual spills in both the cases of operations remain close on operation with a particular series of flow considered. Number of spills are also either same or little more incase of operation with equation which indicates that the amount of spills in each time may be closer to or lesser than the amount of spills in the case of simple operation at a particular time interval.

(c) As regards the number of times the reservoir emptied , it is found that by the operation policy with equation , the reservoir is not emptied at all whereas in the other case , the reservoir is not emptied so many times. Emptying a reservoir is a draw back with many operation policies of a reservoir of a reservoir scheme and this drawback is successfully removed completely this drawback is successfully removed completely with the new technique followed here.

(d)Now referring to the same table one finds there remains more or less closer values of irrigation shortage index for both cases of operation. This could not be eliminated completely by the present set of multiple regressed monthly operation equations.

(iii) From the results tabulated in Tables nos from 6.5 to 6.7. as analysed in more details in respect of no. of times of irrigation deficiency met in each month, the monthly volume of irrigation deficiency, the no. of times of spills in each month the monthly volume of irrigation deficiency, the no. of times of spills in each month and the monthly volume of spills, respective groups were plotted with these values against months as shown in Fig nos from 6.3 to 6.14 for the three sets of reservoir operation in case of historical flows, generated flows of natural series, on both simple operation and operation using equations.

The following features are indicated in these graphs:

(a)It is indicated in the Fig. 6.3, 6.5 and 6.7 that the total numbers of irrigation deficiency faced in the months from April to March in case of multiple regressed operation policy is always higher (except in October) than the case with simple operation policy. It gives the clues that the amount of irrigation deficiency faced in each time of any month in the former case is definitely of a smaller quantity compared to the later.

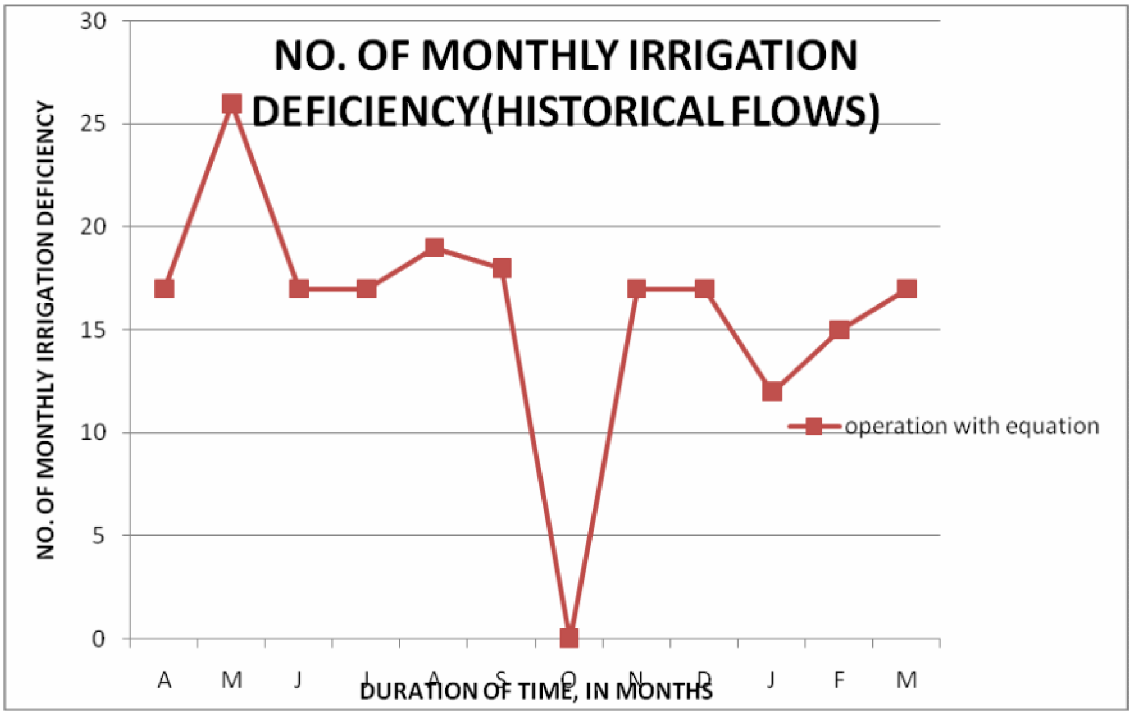


fig.6.1.NO OF MONTHLY IRRIGATION DEFICIENCY (WITH HISTORICAL FLOWS)

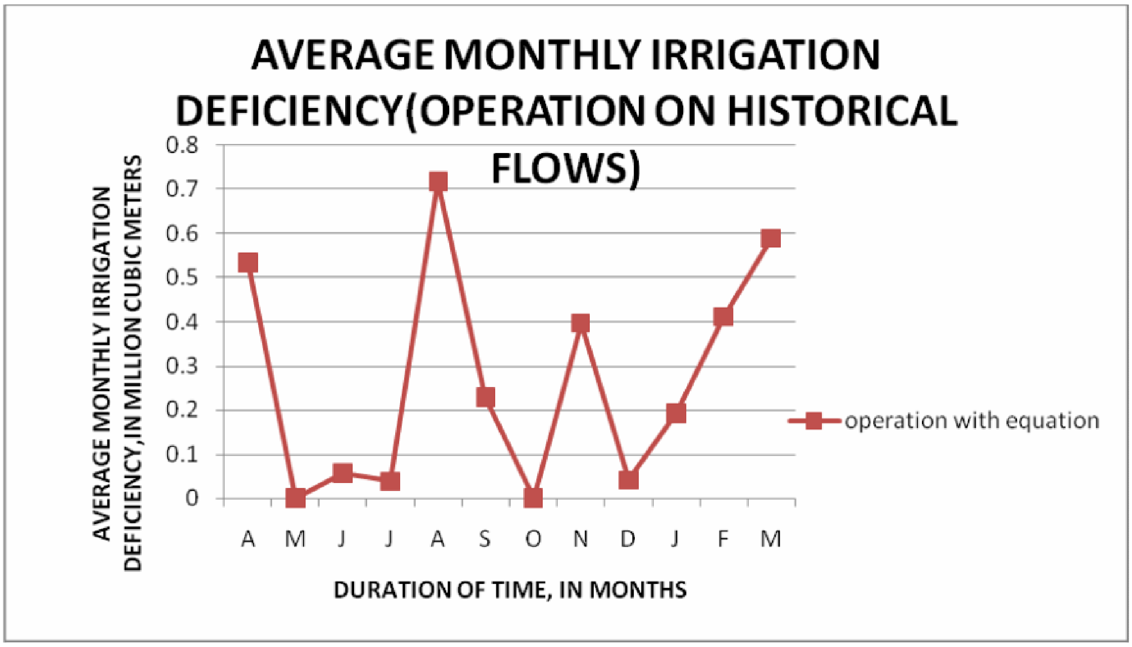
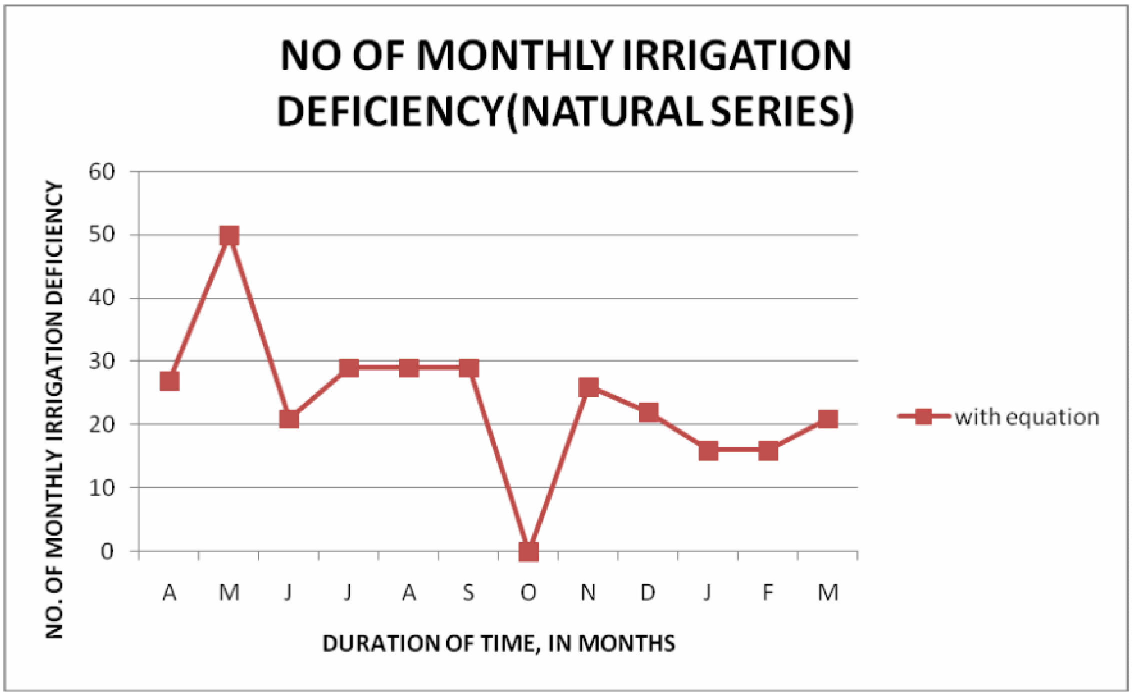


fig. 6.2.AVERAGE MONTHLY IRRIGATION DEFICIENCY (WITH HISTORICAL FLOWS)



6.3.NO OF MONTHLY IRRIGATION DEFICIENCY (WITH GENERATED NATURAL SERIES FLOW)

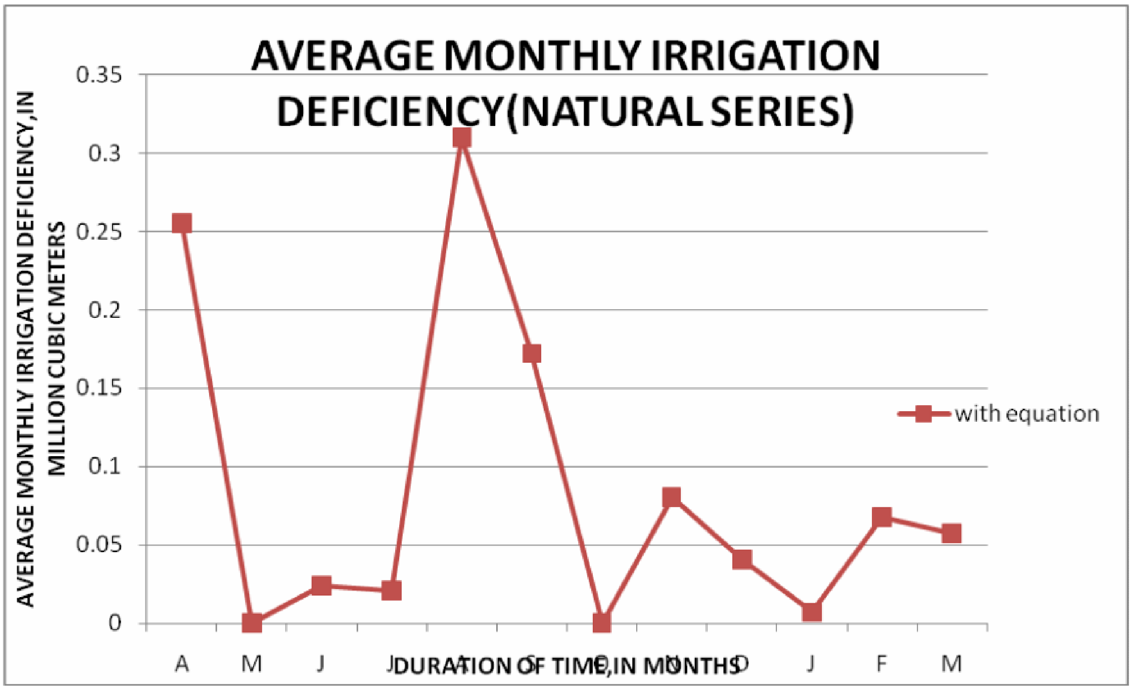


fig.6.4.AVERAGE MONTHLY IRRIGATION DEFEICIENCY(WITH GENERATED NATURAL SERIES FLOW)

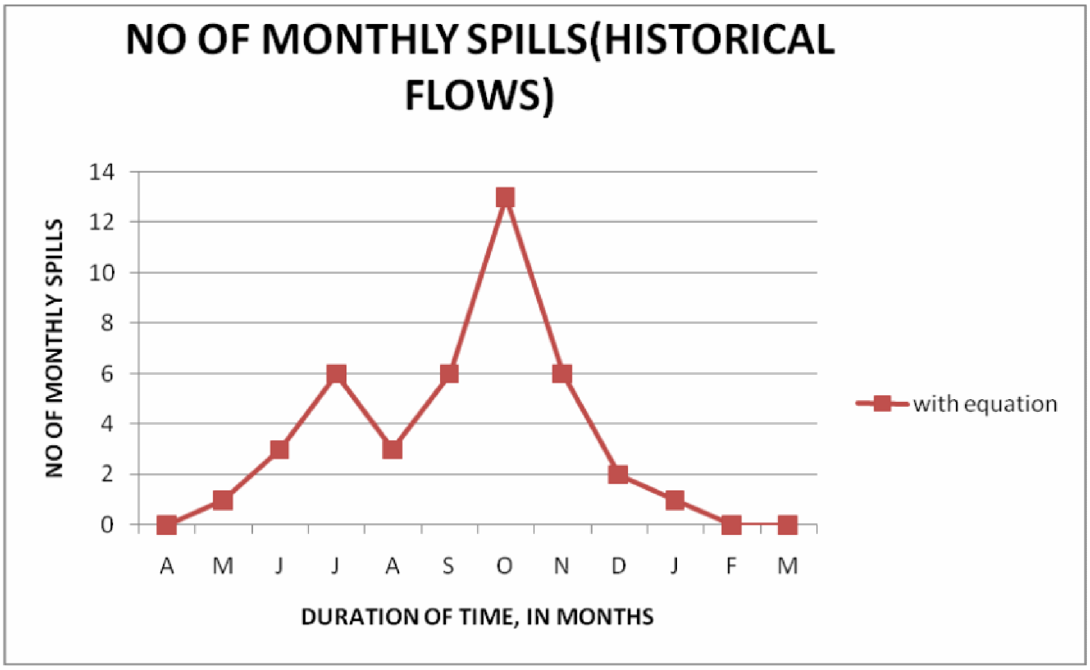


fig.6.5.NO OF MONTHLY SPILLS(WITH HISTORICAL FLOWS)

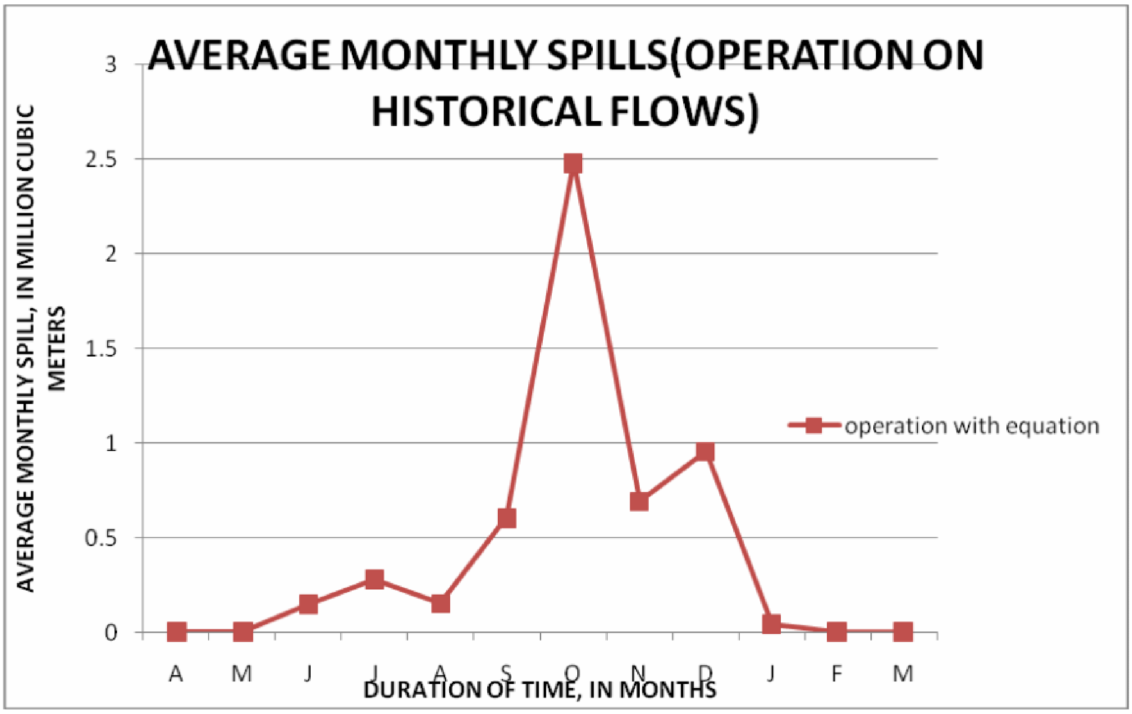


fig.6.6.AVERAGE MONTHLY SPILLS(WITH HISTORICAL FLOWS)

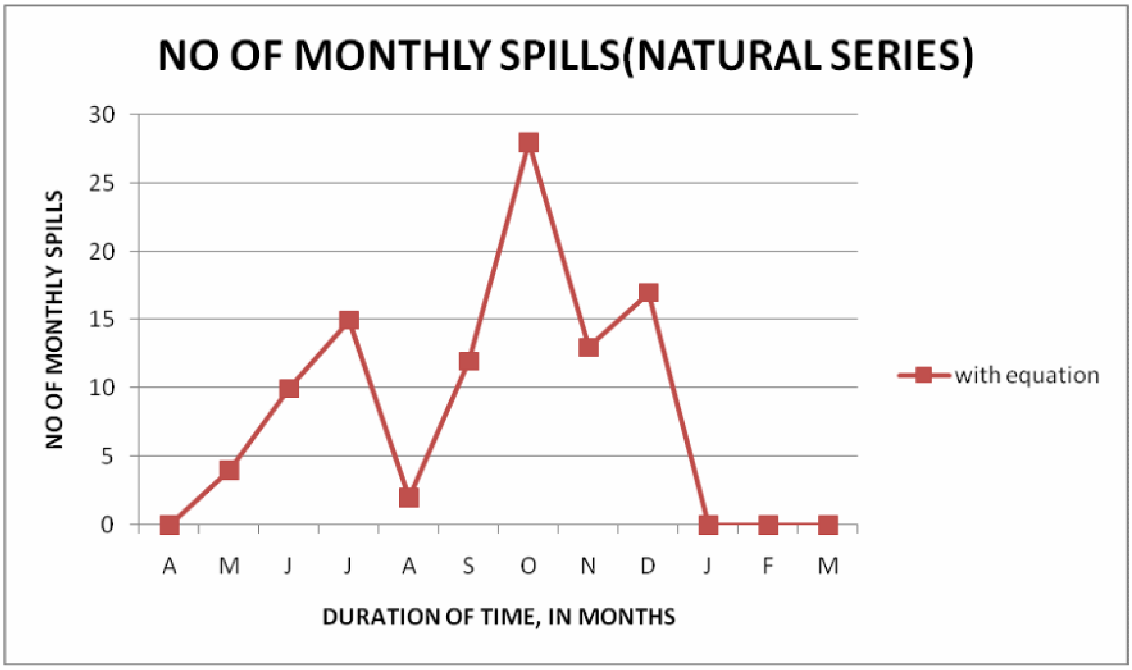


fig.6.7.NO OF MONTHLY SPILLS(WITH GENERATED NATURAL SERIES)

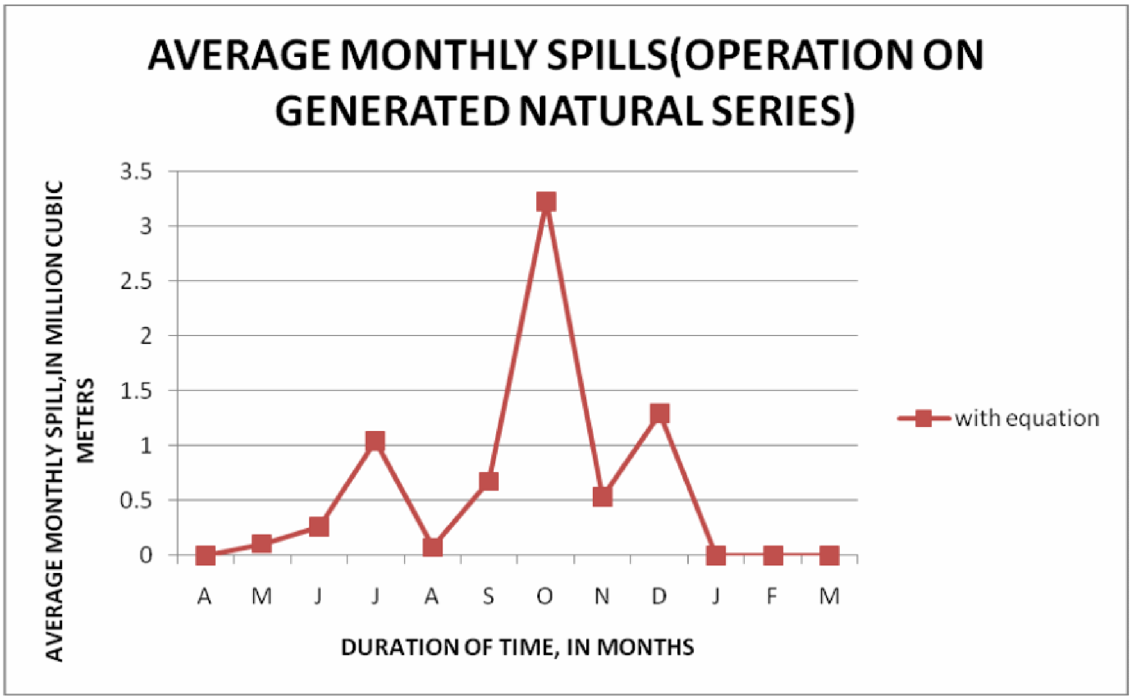


fig.6.8.AVERAGE MONTHLY SPILLS (WITH GENERATED NATURAL SERIES)

In the fig. 6.6 it is found that the average monthly irrigation deficiencies on the adopted multiple regressed policy incase of fifty years of operation with natural series flows do not vary widely as in the case of simple operation. This is obviously marked in the months of August in the above figure where irrigation deficiency due to simple operation is too high.

Comparing both cases of operations for all the three sets of combinations, historical flows and generated natural series of flows, particularly for the dry period such as March, April, May and June. One will see that the volumes of monthly irrigation deficiency in case of multiple regressed operation remain rather close or lower with respect to the average volumes of monthly irrigation deficiency in simple operation probably except in the month of March for the operation carried in case of natural series flows(fig.6.6).

From above features one may opine that the multiple regressed policy bears certain merits over the case of simple operation. The average volume of monthly deficiency in the former case may be little higher in rare months compared to its counterparts but deficiency in each time will amount to very smaller quantity which one can perhaps permit, than facing too much of irrigation deficiency at any particular time.A sort of rationing in case of irrigation deficiency is but certain under drought situation, is to be done and is done actually.

(b)Now coming to the same Tables Nos. 6.5 to 6.7 as referred above and the corresponding graphs in Fig. 6.9 to 6.14 as regards possible spills which are unavoidable for given capacity of reservoir, one will find that the amount of monthly spills in identical months in both cases of operation remain very close to each other. The corresponding number of spills in respective months also remain same with little exception in certain months in case of operation with equation. This indicates that the same amount of spills are spread in more number of times and as such the amount of spills are likely to be reduced in each time, which may be preferred to allowing a great amount of spills in a particular time interval.

(iv) From the results furnished in Table No. 6.8 in respect of probability of failure (6.1) and reliabilities (6.1)of the reservoir, it is encouraging to note that the multiple regressed operation policy is superior and more useful over simple operation due to the fact that the probability of failure is nil here and also the corresponding reliability of the reservoir is one hundred percent. The reservoir is not allowed to remain empty and future uncertainty in case of simple operation is avoided as far as possible.

But referring to the volumetric reliability in both cases of operation, although it is not higher in the multiple regressed policy than the simple case of operation, it is within a permissible limit and not discouraging. There is only two percent of difference in volumetric reliability in both cases of operation. But one will see that the multiple regressed policy also provides as high as 95.53 percentage of volumetric reliability which is easily acceptable and rather encouraging.

This reliability of the reservoir as defined in Chapter 3 perhaps could be still improved by introducing the non-linear concepts into operation policy as one may imagine and the same might be desired along with the multiple regressed operation policy adopted here. In the problem only linear relationships are considered to be existing among the variables and there may be the possibility that nonlinearity may also be involved and this part of analysis needs also be tried, which, in fact, could not be made possible here due to certain unavoidable limitations.

This operation policy based on multiple regressed technique will prove to yield improved results in respects of different aspects of reservoir behavior as studies conducted here , had there been flexibility in operation i.e. in case little excess of irrigation draft over corresponding irrigation demand is determined by this policy and if there will be scope to release this excess amount of water accordingly by increasing the average, then definitely the irrigation supply can be increased, at the same time minimizing irrigation deficiency or spill.

But here restriction is put to limit the irrigation release up to the fixed irrigation demand pattern, hesitating for such a feasibility.

6.3. CONCLUSION:

Surface reservoirs provide major water supply for irrigation. More effective operation of surface reservoirs will certainly provide desired benefits. A number of research have been carried out for reservoir operation with various criteria and constraints. But little specific information is available on the performance of these methods under drought conditions.
1.The present approach of reservoir operation, using multiple linear regressed monthly equations as formulated and applied to proposed Uduthorehalla Reservoir project in the state of Karnataka, has been found very much effective to alleviate drought effects and also useful under normal conditions.
The effectiveness of the technique is reassured by its application to short period of historical flows as well as generated synthetic stream flows for the entire economical life period of the reservoir.
2. In the approach only linearised monthly models have been considered. Perhaps it may yield better operation results if non linearised models will formulated and combined simultaneously in the application for operation in those months where the linearised models bear low values of multiple linear correlation coefficients, which leads to the fact that lower degree of linear relationship among the variables may be due to higher degree of non—linear relationship existing among such variables at certain points of times than the linear once. Hence there is every justification to try this alternative approach with non 1inear concepts.
3.The multiple linear regressed operation policy sounds merits over the simple case of operation, in that due to this approach saving of water as well as a sort of rationing is possible with the available water resource so as to supply irrigation water, specially for a drought prone area as there are critical moments of acute water shortage in the reservoir due to stream flows lower than the normal or no flows at all. If there is anticipated shortage in future due to drought, present planning in always desired to avoid future difficulties. It is hoped that this technique as followed here proves effective in this aspect.

4. Due to this approach there may be irrigation deficiency at certain time. But this irrigation deficiency remains within a very much reasonable limit. With the reservoir operation on the most realistic natural series of generated flows only 4.46% of annual irrigation deficiency may be faced. With the historical flow it is 9.63%.this assures that by this approach always above 90% of irrigation demand can be met in any case.

Now going into details as regards the amount of irrigation deficiency that may be faced due to this approach, one may appreciate that very small amount of irrigation deficiency is permitted each time interval due to a sort of rationing in water supply made possible in the present approach. Perhaps it is wiser to allow each time a small amount of efficiency covered in larger intervals than facing a great amount in a single time interval and to make the reservoir completely empty in future creating further serious problems during droughts.

5. Similar is the case with spills from the reservoir. Almost every time the spill is being reduced as far as possible instead of permitting a great amount of spill in a particular time. This is again possible to some extent by increasing the number of spills, which is but unavoidable.

6. By this approach of multiple linear regressed policies certainly a remarkable success is achieved in that the probability of failure (defined in Chapter 3) according to this operation policy is nil and the corresponding reliability is as high as one hundred percent. The value of volumetric reliability is as high as 95.53% in respect of the most realistic sequence of generated flows of natural series of fifty years covering the entire economical life period of the reservoir.

Thus due to this approach a sort of rationing of water supply to the demand area is effectively done and there remains a chance for saving of some water in the reservoir, to be used exclusively for drought needs. This is definitely one way of alleviating drought effects, where effort is to be made to find some ways and means so as to be in a position to supply at least a certain amount of water always rather than facing critical situations of deficiency where supply cannot be made possible at all due to reservoir emptiness. However, the reservoir operation policy as formulated here not only proves effective under drought conditions but also is useful under normal situations.

This approach is thus as versatile as any other suitable reservoir operation policy.

It is worthwhile here to mention that different persons with diverse interests may ask many questions while a new operation policy is being formulated. Rarely has any policy progressed to yield results to the fullest satisfaction of all. However, if there is a noble aim behind the effort, it inspires for further genuine work which leads to a real success someday, and which may not be too far off. This operation method as applied here is rather a learning process which solves certain problems and faces new ones.

6.4 SUGGESTIONS

As a result of the present work, the research horizon appears to have further widened by giving rise to further area of study in the following lights:

(1) In the multiple regressed monthly operation policy as adopted here linear relationship is considered to be existing between the dependent and the independent variables involved in the problem. But in reality this may not be the fact always. Hence non linear concepts may also be introduced into the linear operation policy and operate the reservoir with the combined policy, so that this may yield better operation results. This aspect needs to be further studied.

(ii) The present set of operational equations are likely to be more effective when adopted with complete flexibility, due to the fact that this technique sometimes determines draft a little more excess in volume than the required demand, and in the problem this draft with such little excess is restricted up to the volume of demand and further operation sequence is carried out. In case there is scope to increase the acreage of the ayacut accordingly by utilizing the excess amount of drafts in such cases and not restricting as usually done here, then this policy will provide more benefits in that the spills as well as deficiencies will be reduced to some extent by avoiding the reservoir accumulation which may lead towards spills and at the same time more draft is likely to be utilized.

(iii)If there is a scope for further development in the area or its neighboring area by creating additional reservoirs for irrigation or any other use ,may be from surface or ground water system and if there is possibility for making grid system among these reservoirs along with this proposed one , then again this multiple regressed operation technique may be more effective , since this techniques sometimes determines draft , little excess of demand and this little excess of water can certainly be made use of by other demand area and mutual saving of water can be done or otherwise mutual shortages can be met to some extent.

(iv)The multiple linear regressed operation rule will also prove useful for operation of reservoirs constructed in areas not affected by droughts. As such the operation rules using the principle of multiple regression will be of much use not only under drought conditions but also under normal situations.

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APPENDIX-A

EQUATIONS TO EVALUATE CONSTANTS AND MULTIPLE REGRESSION COEFFICIENTS.

(i) For the least square regression plane of X_1 on X_2 and X_3 with the equation of the

$$X_1=f(X_2,X_3)$$

i.e. $$X_1=a+b_2X_2+b_3X_3$$

the regression coefficient can be determined by solving the set of simultaneous normal equations as follows:

$\Sigma X_1 - (N.a + b_2\Sigma X_2 + b_3\Sigma X_3) = 0$

$\Sigma X_1X_2 - (a\Sigma X_2+b_2\Sigma X_2X_3+b_3\Sigma X_3^2) = 0$

Assuming

(a) $\Sigma X_1=A$

$\Sigma X_2=B$

$\Sigma X_3=C$

$\Sigma X_1X_2=D$

$\Sigma X_1X_3=E$

$\Sigma X_2^2=F$

$\Sigma X_2X_3=G$

$\Sigma X_3^2=H$

And

$A_1=(A/N-D/B)/(B/N-F/B)$

$B_1=(C/N-G/B)/(F/B-G/C)$

$C_1=(D/B-E/C)/(F/B-G/C)$

$D_1=(G/B-H/C)/(F/B-G/C)$

The regression coefficients can be determined finally from the following

$b_3=(A_1-C_1)/(B_1-D_1)$

$b_2=(A_1-b_3-B_1)$

$A=1/N(A-(b_2B+b_3C))$

(ii) Similarly for a five variable case of multiple linear correction as used in the problem

where $X_1=f(X_2,X_3,X_4,X_5)$

i.e. $X_1 = a+b_2X_2+b_3X_3+b_4X_4+b_5X_5$

the final set of equations satisfying the least square are as follows:

$\Sigma X_1-(N.a+b_2\Sigma X_2+b_3\Sigma X_3+b_4\Sigma X_4+b_5\Sigma X_5)=0$

$\Sigma X_1X_2-(a\Sigma X_2+b_2\Sigma X_22+b_3\Sigma X_2X_3+b_4\Sigma X_2X_4+b_5\Sigma X_2X_5)=0$

$\Sigma X_1X_3-(a\Sigma X_3+b_2\Sigma X_2X_3+b_3\Sigma X_32+b_4\Sigma X_3X_4+b_5\Sigma X_3X_5)=0$

$\Sigma X_1X_4-(a\Sigma X_4+b_2\Sigma X_2X_4+b_3\Sigma X_3X_4+b_4\Sigma X_42+b_{5\Sigma}X_4X_5)=0$

$\Sigma X_1X_5-(a\Sigma X_5+b_2\Sigma X_2X_5+b_3\Sigma X_3X_5+b_4\Sigma X_4X_5+b_5\Sigma X_5^2)=0$

(a) Assume

$\Sigma X_1=A$	$\Sigma X_1X_3=G$	$\Sigma X_2X_5=M$
$\Sigma X_2=B$	$\Sigma X_1X_4=H$	$\Sigma X_3^2=N$
$\Sigma X_3=C$	$\Sigma X_1X_5=I$	$\Sigma X_3X_4=V$
$\Sigma X_4=D$	$\Sigma X_2^2=J$	$\Sigma X_3X_5=P$
$\Sigma X_5=E$	$\Sigma X_2X_3=K$	$\Sigma X_4^2=Q$
$\Sigma X_1X_2=F$	$\Sigma X_2X_4=L$	$\Sigma X_4X_5=R$
$\Sigma X_5^2=S$		

(b) $A_1=(A/N-F/B)/(B/N-J/B)$

$B_1=(C/N-K/B)/(B/N-J/B)$

$C_1=(D/N-L/B)/(B/N-J/B)$

$D_1=(E/N-M/B)/(B/N-J/B)$

$E_1=(G/C-H/D)/(K/C-L/D)$

$F_1=(N/C-V/D)/(K/C-L/D)$

$G_1=(V/C-Q/D)/(K/C-L/D)$

$H_1=(P/C-R/B)/(K/C-L/D)$

$I_1=(A/N-F/E)/(B/N-M/E)$

$J_1=(C/N-P/E)/(B/N-M/E)$

$K_1=(D/N-R/E)/(B/N-M/E)$

$L_1=(E/N-S/E)/(B/N-M/E)$

$M_1=(F/B-I/E)/(J/B-M/E)$

$N_1=(K/B-I/E)/(J/B-M/E)$

$O_1=(L/B-R/E)/(J/B-M/E)$

$P_1=(M/B-S/E)/(J/B-M/E)$

(c)$A_2=(A_1-E_1)/(B_1-F_1)$

$B_2=(C_1-G_1)/(B_1-F_1)$

$C_2=(D_1-H_1)/(B_1-F_1)$

$D_2=(I_1-M_1)/(J_1-N_1)$

$E_2=(K_1-O_1)/(J_1-N_1)$

$F_2=(L_1-P_1)/(J_1-N_1)$

$G_2=(A_1-M_1)/(B_1-N_1)$

$H_2=(C_1-O_1)/(B_1-N_1)$

$I_2=(D_1-P_1)/(B_1-N_1)$

(d)$A_3=(A_2-D_2)/(B_2-E_2)$

$B_3=(C_2-E_2)/(B_2-E_2)$

$D_3=(A_2-G_2)/(B_2-H_2)$

$E_3=(C_2-I_2)/(B_2-H_2)$

Finally the regression constant and coefficients can be determined from the following relations:

$B_5=(A_3-D_3)/(B_3-E_3)$

$B_4=A_3-b_5.B_3$

$B_3=A_2-b_4.B_2-b_5C_2$

$B_2=A_1-b_3.B_1-b_4.C_1-b_5.D_1)$

$A=1/N(A-(b_2.B+b_3.C+b_4.D+b_5.E))$

The forecasting can thus be evaluated from known values of the coefficients a, b_2, b_3, b_4, b_5 with the help of actual or observed values of independent variables X_2, X_3, X_4 and X_5.

APPENDIX B

Matlab program

```
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
%%%%
%%%%%%%                Structure of Network: 4-10-1
%%%%%%%
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
%%%%
clear all
close all
clc
Data = importdata('proj_subodh.txt');
K1 = size(Data,1);

N=K1-2;                             % No. of iterations
for x=1:12
    if x==1
        k1=12;
        k2=11;
    elseif x==2
        k1=1;
        k2=12;
    else
        k1=x-1;
        k2=x-2;
    end
    p=zeros(4,N);
       for y=1:N
            p(1,y)=Data(y,x);
            p(2,y)=Data(y+1,x);
            D=[Data(y+1,k1) Data(y+1,k2)];
            p(3,y)=mean(D);
            p(4,y)=var(D);
       end
       t=Data(3:K1,x);                      % Target Output
```

```
    %%%%%%%%%%%%%%% Initializing the parameters %%%%%%%%%%%%%%%%%%%%%%%%
       w1=randn(10,4)-0.5;                  % Initializing the weights
       w2=randn(1,10)-0.5;
       b1=randn(10,1)-0.5;                  % Initializing the bias values
       b2=randn(1,1)-0.5;

     %%%%%%%%%%%%%%%%%%%%%%%%%%% Iterations %%%%%%%%%%%%%%%%%%%%%%%%%%%%%
        for i=1:N
             a0=p(:,i);
             a1k=w1*a0 + b1;
             a1=(exp(a1k) - exp(-a1k)) ./ (exp(a1k) + exp(-a1k));
             a2= w2*a1 +b2;
             e(i) = t(i)-a2;                     % Error
             s2=-2*1*(t(i)-a2);                     % Sensitivity of 2nd layer
             s1=[1-(a1(1)^2) 0 0 0 0 0 0 0 0 0
                 0 1-(a1(2)^2) 0 0 0 0 0 0 0 0
                 0 0 1-(a1(3)^2) 0 0 0 0 0 0 0
                 0 0 0 1-(a1(4)^2) 0 0 0 0 0 0
                 0 0 0 0 1-(a1(5)^2) 0 0 0 0 0
                 0 0 0 0 0 1-(a1(6)^2) 0 0 0 0
                 0 0 0 0 0 0 1-(a1(7)^2) 0 0 0
                 0 0 0 0 0 0 0 1-(a1(8)^2) 0 0
                 0 0 0 0 0 0 0 0 1-(a1(9)^2) 0
                 0 0 0 0 0 0 0 0 0 1-(a1(10)^2)];
             s1=s1*w2'*s2;                       % Sensitivity of 1st layer
             alpha=0.1;

      %%%% Updating the weights %%%%
             w2=w2-alpha*s2*a1';
             b2=b2-alpha*s2;
```

```
             w1=w1- alpha*s1*a0';
             b1=b1-alpha*s1;
        end
         W1(x,:,:)=w1;
         W2(x,:,:)=w2;
         B1(x,:,:)=b1;
         B2(x,:,:)=b2;
  end

%%%%%%%%%%%%%%%% testing
N1=50;

    p1=zeros(4,1);
    outp=zeros(N1,12);
       for y=1:N1
           for x=1:12
               if x==1
                  k1=12;
                  k2=11;
               elseif x==2
                  k1=1;
                  k2=12;
               else
                  k1=x-1;
                  k2=x-2;
               end
                  w1(:,:)=W1(x,:,:);                 % Getttin the
weights
                  w2(:,:)=W2(x,:,:);
                  b1(:,:)=B1(x,:,:);                 % Gettin the
bias values
                  b2(:,:)=B2(x,:,:);

                  if y==1
                      p1(1,1)=Data(y+N+1,x);
```

```
                p1(2,1)=Data(y+N,x);
                D1=[Data(y+N+1,k1) Data(y+N+1,k2)];
            elseif y==2
                p1(1,1)=outp(y-1,x);
                p1(2,1)=Data(y+N,x);
                D1=[outp(y-1,k1) outp(y-1,k2)];
            else
                p1(1,1)=outp(y-1,x);
                p1(2,1)=outp(y-2,x);
                D1=[outp(y-2,k1) outp(y-2,k2)];
            end
            p1(3,1)=mean(D1);
            p1(4,1)=var(D1);

            a0=p1(:,1);
            a1k=w1*a0 + b1;
            a1=(exp(a1k) - exp(-a1k)) ./ (exp(a1k) + exp(-
a1k));
            a2= w2*a1 +b2;
            outp(y,x)=a2;
        end
    end
 outp
```